# Chromium Plating—A New Process

Thermal Storage System Installed in Modern Plant.

IN the war against the wastage of metals through corrosion, chromium plating is a factor of growing importance. Its work is supplementary to that of stainless steels, and enables the use of non-corrodible materials for decorative and other parts of intricate shape. The use of the process has made rapid strides in sanitary fittings, tableware, motor-car fittings, and a host of other purposes, and there is a promising field for it in engineering work.

A Corner of the Plating Room.

As a commercial proposition chromium plating was practically unknown about five years ago, but in the laboratory it had been of academic interest for a long time. One of the most striking features of chromium plating is the immense variety of trades into which it is being introduced and found to be of extreme value. Mechanical, electrical, structural, and civil engineering have all found the hardness of the chromium to be of great service, because of its resistance to abrasion and erosion. The cotton, wool, silk, artificial-silk, and general textile industries have recognised its property of high resistance to corrosion, from which they usually suffer. Glass manufacturers, and users of all kinds of dies, have adopted the process to their great advantage.

The remarkable progress made in such a brief time is such that articles that have been plated with this metal are rendered absolutely untarnishable. From the point of view of the general public this has an important significance, as the process can be used to reduce the labour in households and public buildings by abolishing the constant drudgery of the polishing of all kinds of metal ware. The very large percentage of ships' cabin fittings now stainless plated is a remarkable testimony to the efficiency and progress made since the inception of the process as a commercial proposition.

Chromium, discovered about the year 1879, is a silvery white hard crystalline metal, which is usually obtained by reducing the oxide with aluminium. Its melting point is approximately 1,510° C., and its association with iron and steel to make them non-corrodible is well known. Deposited in the form of plating, it is possible to give it a polish of a very high brilliancy, which does not tarnish. It is very hard, much harder than nickel, and, in consequence, does not readily wear off. Further, the plating will withstand great heat, and because of its non-corroding properties forms an economical protective coating.

In order to understand the commercial value of chromium plating, nickel and silver plating should be taken for comparison, since in many cases chromium plating is intended to replace these. It will be appreciated that chromium plating has a far more useful field of application than either nickel or silver, because of its two main characteristics—namely, extraordinary hardness, and its resistance to corrosion. Any comparisons, for the moment, are therefore reserved to the method and not the results.

NICKEL AND CHROMIUM PLATING.

Briefly, the essential differences between the methods of nickel and chromium plating are as follows :—
In nickel, as also in silver, the anode consists of the actual metal to be deposited, and as such is called a soluble anode, while in chromium plating an anode of lead or iron (generally lead) is used, the chromium deposit being supplied from a solution of chromic acid in the bath. (To avoid confusion later on, it should be stated here that chromium is one of the metallic chemical elements, at. weight $52 \cdot 1$, and that it is not found in the free state in nature. It occurs chiefly as chrome-ironstone, Cr_2O_3FeO, and is shipped in the crystalline form, which forms the base of the acid, largely from Rhodesia.)

The cathode which is used in the acid bath is always the article to be plated in each case ; also, in nickel and chrome, other chemicals are present in the bath to complete the process. The latter, however, do not affect the principle.

OTHER COMPARISONS WITH NICKEL AND SILVER.

We have explained briefly where the methods of plating differ. It is now possible to discuss the problem a little more deeply. Nickel and silver both tarnish ; chromium does not, but the former, nevertheless, has certain advantages so far as the practical business of plating is concerned.

(1) As nickel and silver can be applied at a considerably quicker rate, it is possible to lay such a rapid coating of these over a pitted or cracked surface that the irregularities can be filled up and the under-metal entirely sealed from the air. Chromium, being more slowly applied, follows faithfully the contours of the under-surface. In order, therefore, to obtain a perfect finish, the under-surface must be ground or buffed free of blemishes before attempting to plate.

(2) Nickel and silver, on the other hand, appear not to form any close metallic connection with the surfaces which they cover, and are capable of being chipped or peeled.

Chromium forms a much better " liaison," and will resist these defects permanently. One of its main advantages is that it will neither chip nor peel.

(3) Owing to the very ready manner in which nickel and silver can be deposited, and also owing to the fact of the natural element forming the anode, cracks, seams, and inaccessible nicks can all be covered to the required
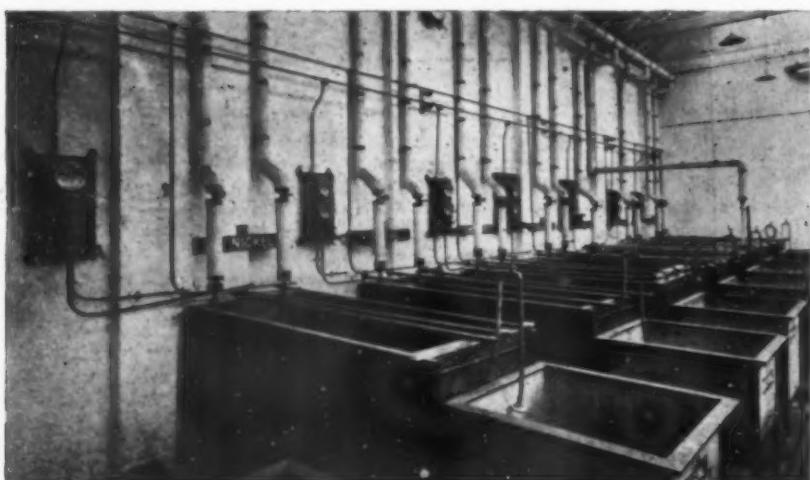

Another Corner of Plating Room.

deposit. In chromium plating, owing to the rapidity with which hydrogen is liberated during electrolysis, considerable interruption to deposition can occur on any but an open surface. Thus, the undersides of collars, shoulders, beadings, and ledges will receive an inadequate deposit unless special measures are taken against it.

The same remarks apply to cup-shaped vessels or the interior of tubes, and the difficulty in all cases is overcome by an anode specially shaped to the contours of the surface, limited only by the ingenuity of the man responsible for wiring the job.

(4) The comparison is drawn from the two outstanding qualities of chromium as against nickel. Firstly, nickel is soft and chromium is extremely hard ; secondly, chromium is rustless, and amalgamates with the metal to an extent which nickel does not. There are two qualifications to these remarks which must now be stressed.

Hardness.—In deciding how hard the chromium surface is to be, the state of final brilliance must be considered, for if the current is very high in the bath, or the immersion a specially long one, the plating will be very hard. The resultant *matt* finish can, therefore, only be buffed bright by prolonged polishing. Consequently, extreme brilliance can only be *economically* obtained at a certain expense of hardness.

Rustlessness.—Unless the metal to be covered is itself non-corrosive, such as brass, copper, or nickel, it is necessary first to cover it with a protective coating of some such metal. For instance, if iron or steel are to be chromium plated they must first be brassed, coppered, or nickelled, and the result chromium plated. This particularly applies, of course, in the event of the finished article being used under damp conditions. It will have been assumed from the foregoing remarks that chromium is porous.

It only remains to add a word on the final brilliance of chromium. Apart from the operation of buffing, the surface of the under-metal has always an all-important influence. Owing to the characteristic of the chromium following faithfully every contour of the surface, as previously stated, the finished surface will have the same irregularities. Therefore, any surface for which a brilliant finish is required must itself be highly polished before plating.

In England chromium is deposited under a large number of processes, but hitherto really satisfactory results, particularly in relation to brilliance and durability, have only been obtained when chromium was deposited on a layer of nickel plating, irrespective of the base metal. By utilising a special chromium-acid mixture, the Northern Chromium Company, under the direction of Dr. Nast, a well-known German chemist, who has been entirely responsible for the new process, is successfully depositing chromium direct on to brass or copper and non-ferrous metals.

The process holds out two outstanding advantages :—

(*a*) By plating direct, the time wasted in nickelling and rebuffing is not only obviated, but the risk of the nickel plating parting company with the main body and bringing with it the chromium covering owing to peeling and chipping, is equally effectively " scotched."

(*b*) By plating direct, the total costs are greatly reduced on account of the saving of the lengthy nickelling process. (An article needs a forty minutes' immersion to nickel plate as against about ten minutes in a chrome bath, meaning that apart from the cost of the extra process itself, about four nickel baths are required to be installed to every chromium bath, if the work is not going to be held up through congestion in the nickelling department.)
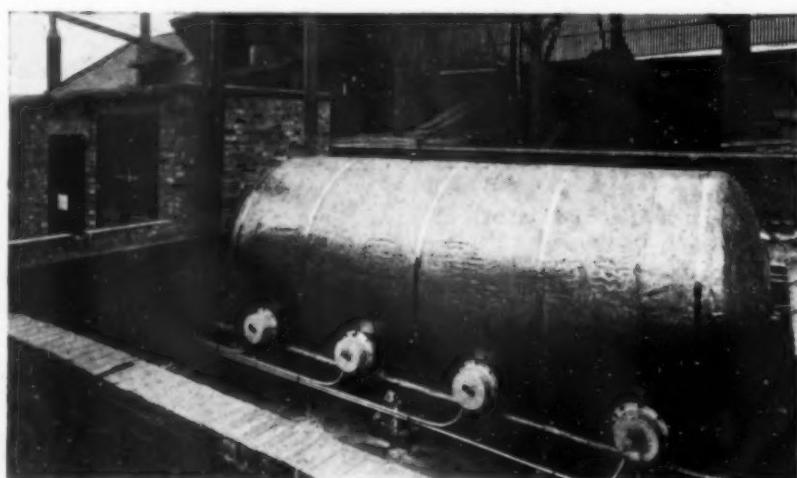
General View of 5,650-gall. Storage Tank, showing the projecting ends of the four 30-k.w. banks of immersion heaters.

Chromium may also be deposited on iron or steel, but where there is a possibility of rust, these metals are first treated with a special application of cadmium, which renders them rust-proof, and then the chrome may be deposited direct, or, alternatively, a nickel-plated coating or brass coating, depending on the ultimate finish required.

Cadmium, being of a soft nature, can neither be buffed very brightly without danger of removal from the base metal, nor will it permit, for the same reason, of the chromium being highly buffed, if buffed at all. Thus, the Northern Chromium Company's process has broken away from the principle of always associating nickel with chrome. Summarised, it can be said that its outstanding feature is its ability to plate directly on to copper, brass, and other non-ferrous metals.

The Company's plant at Newcastle includes several unusual features, particularly in regard to the thermal storage equipment, and the methods of disposing of the dangerous chromium-carrying hydrogen bubbles, which are liberated in great quantities during electrolysis. The latter can be most conveniently explained first, and this by briefly following the operations of a simple article which has come into the works for plating.

(1) An article—say, a used motor lamp—is dismantled and de-nickelled.

(2) It is ground and buffed, until the base metal has a perfect polish.

(3) It is wired by experts for hanging into the chromium bath in such a way that all parts of the surface will get a fair share of the deposit. This is an expert's job.

(4) It is degreased in a special bath. (This is necessary through a brilliant invention of Dr. Nast's, which has a direct bearing on this method of plating, particularly in connection with the low cost.) When chrome is being released from the acid in the chrome baths hydrogen bubbles, thinly coated with minute quantities of chrome, rise to the surface. These bubbles are lifted into the air by the hydrogen, and form a serious menace to the health of the workers unless drawn away. An elaborate and very costly system of exhaust and filterage is usual, but Dr. Nast has prepared an oil which he floats on the surface of the acid. This oil de-coats the hydrogen bubbles of chromium as they pass through to the surface, to be liberated as harmless hydrogen.

The article to be plated has to pass through this layer of oil on its way to the acid. Hence the necessity for it to be thoroughly degreased, so that when it is passed through the oil (after it has been wetted) no oil adheres to the surface. The principle is the same as water flowing off a duck's back.

Close-up view of one of the 30-k.w. Banks with end-cover removed, showing arrangement of bus-bars. The method of connecting the single heater units and the incoming supply to the bus-bars is clearly shown.

This description would not be complete without a mention of the new patent chromium plating tank, which is being specially designed for the plating of small articles, such as screws, etc. The size of this tank is 7 ft. long × 3 ft. × 4 ft. deep, and when installed this machine will be capable of dealing with these small articles by the ton, eliminating the wiring-up process, and so making the chroming of such small articles an economical proposition. This machine will be the first of its type to be put into commission in England.

The extensive plant recently installed by this company for chromium plating by Dr. Nast's new process, and for which they have the sole rights in Great Britain, is naturally of a modern character. It is probably the first plant installed in Great Britain in which a thermal storage system has been applied to industrial heating. In all, there is a total of 24 large tanks, which have to be maintained at temperatures varying between 70° F. and 140° F. These include chromium-plating tanks, hot-saw-dust tanks, hot-water tanks, de-greasing tanks, and acid baths used for copper, nickel, and aluminium plating. Each tank is fitted with a heating coil of steel or lead, depending on the nature of the electrolyte; and this coil is connected through valves on the inlet and outlet side to hot-water mains run round the building. One of these valves is a check valve, and is usually fully open, regulation being carried out on the other valve.

One of the 30 k.w. Banks before being fitted into the storage tank, showing the arrangement of the nine single-phase heating tubes.

(5) The article comes out of the chromium bath with a beautiful surface, which requires very little polishing. A note should be made here concerning hardness. In the case of some articles it is desirable to plate specially hard, and the maximum degree obtainable is actually 95% of the hardness of a diamond. The hardness depends directly upon the amperage per square foot in the chromium bath.

The whole system is efficiently lagged, and the supply of hot water is taken from the large thermal storage cylinder installed in a pit outside the main building. This cylinder, which is 18 ft. long × 8 ft. in diameter, holds 5,650 gals. of water, and is heated by immersion heaters of a total capacity of 120 k.w., supplied by Messrs. A. Reyrolle and Co., Ltd., and arranged in four 30-k.w. banks. Each bank consists of nine 3·3-k.w. heating units mounted on a common flange-plate, with their connections brought out to terminals on a set of four circular bus-bars. The supply is 3-phase at 440 volts, 40 cycles, and three of the bus-bars are connected to the outers, while the fourth forms a star point. The heating units are so arranged that the load is equally divided between the three phases.

Energy for heating the cylinder is supplied at special rates, during the night hours only, from the mains of the Newcastle-upon-Tyne Electric Supply Co., Ltd. Current is automatically switched on by a time-switch at 7·30 p.m., and continues to flow until the water in the main cylinder reaches a temperature of 220° F., when it is switched off by a thermostat.

In the morning the main stop-valve is opened, and a small circulating pump is started up, to pump hot water at a temperature of 220° F. round the heating system, thus making heat energy immediately available for heating up the various tanks required for the day's work. At the end of the day the water is at a temperature of 140° F., which implies a total heat storage equivalent to 1,320 k.w.-hours. It has been found that the majority of the tanks can be brought up to the required temperature within three-quarters of an hour after starting up the circulating pump.

The alternative to the above method of heating would have been the installation of a steam boiler, and each of the 24 tanks would have had to be fitted with a steam-trap, and, further, a connection to the steam-trap would have had to be taken through the bottom of the tank. This joint would always have been a possible source of leakage, allowing valuable electrolyte to escape to the floor of the plating-room. Further, the replacement of a heating coil could only have been carried out by emptying the tank, whereas with the scheme of hot-water heating actually in use this can be done by merely breaking the joints and lifting the heating coil out of the tank.

It should also be remembered that the demand for heating is very heavy early in the morning, when the tanks are being brought up to temperature. It would therefore have been necessary to start firing the boiler a few hours before the beginning of the day's work, so as to reduce the danger of boiler-priming, and for the remainder of the day the boiler would have been working inefficiently on a very light load to maintain the tanks at their appropriate temperatures.

It will thus be seen that thermal storage heating has simplified the installation of the heating coils in the tanks, and has also made the system much cleaner and easier to maintain. Labour has been reduced, because the operation of the storage cylinder is entirely automatic, and the only labour involved is that of opening and closing the stop-valve, and starting up or shutting down the circulating pump.

FUTURE APPLICATION OF CHROMIUM.

In conclusion, it is interesting to look over the present and probable future applications of chromium plating. As it is possible to plate 95% as hard as a diamond, its future scope includes the vast field of engineering tools, dies, moulds, etc. In the more popular section of the engineering world there is every reason to believe that the future will see its universal use on the bright parts of tram-cars, motor-cars, motor-cycles, aeroplane fittings, etc., etc.

There is a big scope also for its use on the railways for carriage door handles, interior fittings, and for domestic use on all household fittings where time and labour are at present spent on cleaning. For the electrical industry much the same conditions are present. Anything from switchboard fittings to wireless parts can be chromium plated to definite advantage. Some of the possible applications in collieries are the plating of haulage ropes to overcome the bogey of corrosion, engine gear, instruments, miners' lamps, and pithead bath fittings. In each of these spheres enormous sums are spent annually in cleaning and in preventing corrosion, all of which can be economically saved.

MACHINING MANGANESE STEEL.

MANGANESE steel has always presented difficulties in its resistance to machining, and experimental work on cutting this material facilitates the solution of the problems associated with its machinability. Some tests have been carried out with a D.G.D. super high-speed steel on a manganese steel bar 5¾ in. diameter, which was forged and water quenched at 1,030° C., giving a Brinell impression of 4.2. An analysis of the bar gave the following composition :

Carbon.	Manganese.	Silicon.	Nickel.
1·01	13·90	0·23	0·18

The particulars of the tool, which is shown in the illustration, will be of interest. In section it was 1¼ in. × 1 in., having a round nose, both front and side clearances being 7°, the top rake 8°, and a side rake of 14° making a combined angle of 69°. The tests and results, obtained at the Openshaw works of the English Steel Corporation, are indicated in the accompanying table.

Cutting Speeds in Ft. per Min.	Depth of Cut.	Feed.	Duration in Minutes.	Remarks.
14	⅛ in.	1/60 in.	40	Still kept size and in good condition : Reground for Test 2.
14	⅛ in.	1/60 in.	57	Showed signs of wear. Reground for Test 3.
11	⅛ in.	1/60 in.	90	Began to show signs of wear.

Blast Furnace and Larger Stacks

Increased Capacity Necessitates Development in Auxiliary Equipment and a Wider Use of Gas.

THE blast furnace continues to be the largest industrial producing plant in modern times. A few years ago a production of 200 to 300 tons of pig iron per day from a furnace was considered to be good practice, while to-day 1,000 tons per day from a furnace has been exceeded, and production maintained at this rate for over twelve months. Apart from this, many blast furnaces are now operating that have an average daily output between 900 and 1,000 tons. This remarkable progress is the outcome of many developments during recent years, developments that have not only affected the blast furnace, but all subsidiary equipment necessary in the blast-furnace plant. The tendency has been towards larger-capacity furnaces in order that the burden could be considerably increased, and it is difficult to foretell the limits that may be imposed upon the size of furnace in the future by economic considerations. These developments have necessitated a wider use for blast-furnace gas and changes in the methods of charging. In addition, the importance of auxiliary equipment, never more fully recognised than to-day, has necessitated improvements in blowing, heating, and steam-generating equipment. A number of structural changes have been made in the stacks of blast furnaces, and these have made changes in the whole plant. The hearth diameter has been increasing by a few inches a year, but a radical change has been necessary to enable a single stack to accomplish the production of 1,000 tons of pig iron a day.

UNUSUAL INCREASE IN SIZE.

In 1927 a furnace was built having a hearth diameter of 24½ ft., or about 3 ft. larger than that of any previous design. While this furnace did not produce 1,000 tons per day immediately, it did make more than 900 tons, notwithstanding the fact that the top had been left disproportionately small, and in spite of inadequate blast-heating facilities and an uneven grade of coke. A few months later, under improved temperature and fuel conditions, this furnace was regularly making 1,000 tons daily, and for 1928 had a total output of 368,000 tons, or a daily average production of 1,008 tons. This was accomplished by the personnel of the Jones and Laughlin Steel Corporation, without proper adjustment of the other parts of the equipment to the greatly increased demands made by the increased output. There has been considerable hesitancy about enlarging the furnace tops proportionately, according to Arthur G. McKee in a paper presented at the national meeting of the Iron and Steel Division of the American Society of Engineers, even in furnaces having a hearth diameter of 21½ ft. This was doubtless due to the fact that larger hearths were fitted to small stacks to avoid the cost of complete rebuilding, but even where new shells have been installed the top diameter of 17 ft. to 17½ ft. was reproduced. Retarding top development has been one cause of the seriously increased flue-dust losses that have attended the large units, and much greater volume of blast which they have required. Recently three furnaces have been blown in, having a top diameter of 19 ft., the diameter of hearths being 19 ft., 21½ ft., and 25 ft. respectively. In each case the practice has been improved, particularly in regard to flue-dust production. Losses in each case have been about 150 lb. of dust per ton of pig iron, whereas with the smaller tops 200 lb. to 400 lb. was common practice. The two furnaces, having 21½ ft. and 25 ft. diameter hearths have been designed to have an increased distance between the bell and the stock line. The customary distance of 2 ft. was altered to 2½ ft. The distance is important in securing the right distribution of

the burden, and this apparently small change may to some extent be responsible for the improved results obtained from the use of larger tops.

At present the largest furnace has a 27½-ft. hearth, but the stock line is only 18 ft. The advent of the 25-ft. hearth has caused renewed study of furnace dimensions. The following figures were suggested as being suitable for a modern furnace producing 1,000 tons of pig iron daily.

Hearth diameter	25 ft.
Bosh diameter	27 ft.
Burden line diameter	20 ft.
Bell diameter	15 ft.
Total height	95 ft.
Bosh height	10 ft.
Straight section above mantle	10 ft.
Angle of bosh	84° 17 ft.
Slope of inwall	⅞ in. per foot.

None of the larger furnaces in use to-day are new furnace plants, although they have necessitated a corresponding increase of capacity in the auxiliary equipment. In all cases the stock houses, stoves, and blowing equipment were originally designed and built for furnaces of 500 tons capacity or less. It is unlikely that many additions to the number of furnaces to existing plants will be made, for the obvious reason that capacities are increased more readily and economically by enlarging the existing stacks. This has led to a decrease in the total number of active furnaces, although the potential capacity and actual output have been increased. Developments in stock-house construction is definitely toward central coke bins, preferably having facilities for weighing the coke, double-compartment cars, and double skips of large capacity. Skips, hoists, and bell-charging appliances are larger, and are electrically operated.

In connection with the blowing equipment, Mr. McKee considers that turbo-blowers have proved particularly well suited for the larger furnaces, being highly efficient in operation, and occupying a comparatively small amount of floor space. Substituting turbo blowers for reciprocating engines, it is possible to more than double the blowing capacity which can be housed in a given area. Modern large-capacity boilers have made it possible to meet the increased demands of the furnace plant for steam by replacing the many small units formerly used, requiring much less space per unit of capacity.

It is of considerable importance to note that pulverised coal is finding more favour as an auxiliary fuel to blast-furnace gas. It may be that the chief reason is the ease with which a change can be made in comparison with stokers. The auxiliary firing is automatically controlled at one large installation of this type, and is stopped or started according to whether the supply of gas meets the demand of the plant for steam.

The most important developments in auxiliary equipment, however, have been in connection with blast-furnace stoves and gas-cleaning equipment. The matter of stove construction has been brought into prominence recently, both by the requirements of the larger furnaces and the great appreciation of the value of blast-furnace gas for other purposes. Increasing the size of blast furnaces has made it imperative to secure greater blast-heating capacity, while the value of gas has emphasised the importance of gas conservation through higher stove efficiency. The improvement in furnace practice which has made the use of higher blast temperatures possible is another reason for developments in stoves. Temperatures from 1,200° to 1,500° are now common practice, being probably 200° to 300° higher than the average of a few years ago.

The older furnaces were generally equipped with four stoves each, which varied greatly in size and type of checker work. The average size of the old two-pass stoves would probably be about 21 ft. × 100 ft. Many of the stoves still in use were built more than 20 years ago, previous to the general adoption of wet cleaning of blast-furnace gas, and are still lined with the large checker openings which the use of dirty gas made necessary. A
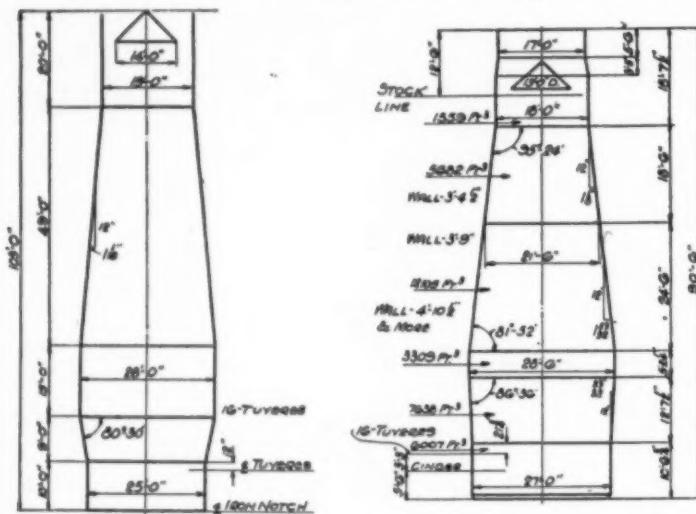
LINES OF TWO MODERN-1000-TON FURNACES
Dimensions of two 16-tuyere stacks designed for a 1,000-ton daily ouptut.

heating surface varying between 35,000 and 50,000 sq. ft. was customary. Under such conditions high stack temperatures were unavoidable. In many cases the temperature of the stack gases would be equal to or greater than that of the blast leaving the stoves. Blast-furnace slag was generally used for insulation, and between high radiation losses and stack losses the thermal efficiency of such stoves would be seldom higher than 60%.

The advent of gas scrubbers facilitated the use of smaller checker openings, with the result that many of the old stove shells have been relined during the past decade with openings varying from 3½ in. to 5 in., and with brick as thin as 2 in. In the construction of this type it has been possible to almost double the heating capacities at certain plants merely by relining the stoves with smaller checkers. During the same periods the use of better insulating materials has reduced radiation losses. The use of pressure burners has further increased the capacity of existing stoves, but, unless the heating surface has been largely increased to absorb the heat from the increased volume of hotter gas, they are used at the expense of stove efficiency through increased stack temperature. The improvements resulting from smaller checkers, better insulation and pressure burners, are associated with the general increase in furnace capacity during the period extending from 1914 to 1928, during which time the average daily capacity has been increased to between 500 and 750 tons.

The modern blast furnace, especially when operated in conjunction with steel plants and rolling mills, will soon be supplying blast-furnace gas for many different metallurgical purposes, and must be provided with stove equipment which is ample for blast-heating requirements, and at the same time highly efficient in use of gas, which, in that case, becomes a valuable product. Radiation losses must be reduced to a minimum, and stack temperatures low. Checker openings must be as small and the walls as thin as is consistent with the cleanliness of the gas to be used and the structural strength required.

The stove-heating surface required under modern conditions for each ton of pig iron produced per day is

about 400 to 500 sq. ft. Thus a furnace producing from 1,000 to 1,200 tons per day should have 400,000 to 550,000 sq. ft. of heating surface in its stoves, or a little over 100,000 sq. ft. per stove where the usual number of stoves are employed. To provide the necessary additional heating surface, some builders have preferred to increase the size of the stoves or reduce the size of checkers as small as 1 in. diameter. This practice makes complete cleaning of the gas imperative, and the holes are susceptible to closing from any slight shifting of the checker work. The resistance offered to the travel of the gas through them is also high, requiring more pressure at the burners, or a much higher stack to overcome it.

Blast-furnace engineers have long recognised that smaller checker openings and thinner checker walls were necessary to get the much greater heating surface required into the present small stove shells, and that it was impossible to support such small checkers on firebrick arches and girder tiles. In order to get the required heating surface in small checkers and to support them safely and permanently, a new type support for the checker work was recently developed in the form of columns and high chrome nickel-steel alloy grids. These support the entire bottom surface of the checker structure, so that it is impossible for the checkers to shift or break down unless from the failure of the grids. A factor of safety of 15 to 1 at a temperature of 1,000° F. has been used in designing these grids, so that the possibility of failure of the checkers or their supports has been practically eliminated. This new type of stove is self-supporting and free to expand vertically, independent of all other units, so that there are no undue strains set up by unequal expansion of the different parts. The use of extremely small checkers has been avoided, and a large heating surface has been secured. The checkers may be started near to the bottom of the stove, and at the same time have unusually large passages for the gas and blast. The checker tiles are so interlocked with each other that they cannot become displaced laterally, and, at the same time, the individual checker tiles are free to expand vertically.

This construction affords strength, durability, and unobstructed access to the checker openings, and permits large reduction in the more or less unutilised space below the checkers. More even distribution of the gases over the entire area of the checker work also results, which tends to increase both the capacity and the efficiency of the stove.

With blast-furnace gas of the cleanliness obtained from washers of the Feld type, containing less than 0·25 grain of solids per cubic foot, it is feasible to use checkers as small as 2¾ in. square or 3 in. round. A 21 ft. × 100 ft. stove lined with 2¾-in. checkers and metal bottoms, and having 2½ in. insulation, will have 108,000 sq. ft. of heating surface. Four stoves of such design are probably ample to provide adequate blast-heating capacity for the largest size furnaces, while maintaining a high degree of thermal efficiency, although such a combination of equipment as a 1,000-ton furnace, and stoves of 432,000 sq. ft., has never been tried. However, four 22 ft. × 100 ft. stoves would provide 480,000 sq. ft. of heating surface.

Closely associated with the improvements in stove construction, and particularly with the use of blast-furnace gas at coke plants and in the mills, has been the matter of better gas cleaning. Previously, the complete elimination of dirt from the gas has been held to be necessary or justifiable only when the gas was intended for use in gas engines. The drum-type Theisen scrubber was generally used for this purpose. Where the gas was to be used for stoves or boilers the use of the Feld-type washer has been generally adopted. The cleaning efficiency of these two types of cleaners may be roughly compared by the

statement that the Feld-cleaned gas will usually contain less than 0·2 grain of dust per cubic foot, and Theisen-cleaned gas less than 0·02 grain.

The disintegrating type of cleaner is one which was developed in Germany in an effort to obtain gas of Theisen cleanliness with a smaller expenditure of power. Several German firms now make disintegrators, including Theisen, and they have come into general use abroad. While accurate data are not yet obtainable for American practice, it is probable that their cleaning effectiveness will compare favourably with that of the drum-type Theisens. It appears that the power requirements will be about one-half that used in old-type Theisens.

Another promising development lies in the application of the Cottrell precipitators to wet gas. A small plant of this type used in conjunction with primary tower washers has consistently cleaned down to about 0·01 grain per cubic foot. Apparatus of this type has a distinct advantage in power and water consumption over any mechanical scrubbing device. The following table based upon the best obtainable data may be of interest :—

REQUIREMENTS, PER 1000 CUB. FT. GAS.

| | Final Cleaning— | | Nonboosting. |
	Theisen.	Disintegrators	Cottrells.
Water, gals.	10	10	0·6
Power, kw.h.	0·1137	0·0564	0·0084

While rapid progress is being made in the development of better and more economically operated devices, the final cleaning of gas is still an expensive procedure, and is as yet only justified where ultimate cleanliness is an operating necessity. There is, however, a rapidly growing demand for thoroughly cleaned gas brought about by the extension of its use for under-firing coke ovens and in the steel mills.

Until recently, in normal American practice, the use of blast-furnace gas has been limited generally to the heating of stoves and the generation of steam. In some few plants it has been used in gas-engine driven blowers and electric-power generators. The past year has witnessed the inauguration of underfiring coke ovens with blast-furnace gas. Two merchant furnace plants having adjacent by-product coke ovens are now using this means to increase their revenues by releasing large additional amounts of coal gas for sale to domestic users.

Coke produced in ovens heated by blast-furnace gas has proved to be of more uniform quality than when the same ovens were fired with coal gas, and the blast-furnace practice is said to have been improved as a result of the change.

Where there is a domestic market for coke-oven gas, the utilisation of blast-furnace gas for firing coke ovens will undoubtedly be most productive of profit. About 25% of the gas produced in the manufacture of a ton of pig iron can be utilised in this fashion, or approximately 35,000 cub. ft. per ton of pig iron produced. This will replace and release for sale about 6,000 cub. ft. of coal gas.

Gas for the steelworks is further cleaned in Theisen disintegrating washers to a cleanliness of approximately 0·02 grain per cubic foot. The gas is also boosted by the disintegrators to 20 in. of water pressure and discharged into a 1,000,000 cub. ft. gas-holder near by. From the gas-holder, it is distributed through one main to the open-hearth plant, and through another to the steel mills. These are overhead mains, and have a total length of 1,200 ft. and 1,400 ft. respectively.

In close proximity to each point of consumption has been located a station for the mixing of the two gases. The design of the mixing devices is such that any desired proportions of the two gases may be obtained and automatically maintained. Thus, the value of the gas may be correctly adjusted to the particular requirements of each steel-making or heating unit.

The peculiar advantages of a mixed gas system will be readily apparent. No two of the various heat-treatments which are employed in the manufacture of steel products will call for the same intensity and quantity of heat. Mill practice, therefore, will be improved when the B.th.u. value of the fuel employed is accurately adjusted to each particular use. The two fuels, blast-furnace gas of about 90 B.th.u., and coke-oven gas of about 550 B.th.u., furnish a means of accomplishing an ideal fuel by mixing.

The monetary advantages which may accrue from the installation of a complete system for cleaning and for distributing blast-furnace gas to the steel mills may only be arrived at by a careful examination and study of the economic and operating conditions which obtain in the plant and locality under consideration. Among the factors which must be considered are the quantity and quality of the blast-furnace gas available and its value for steam raising based upon the cost of steam coal ; the supply of coke-oven gas and its commercial market value, if any ;
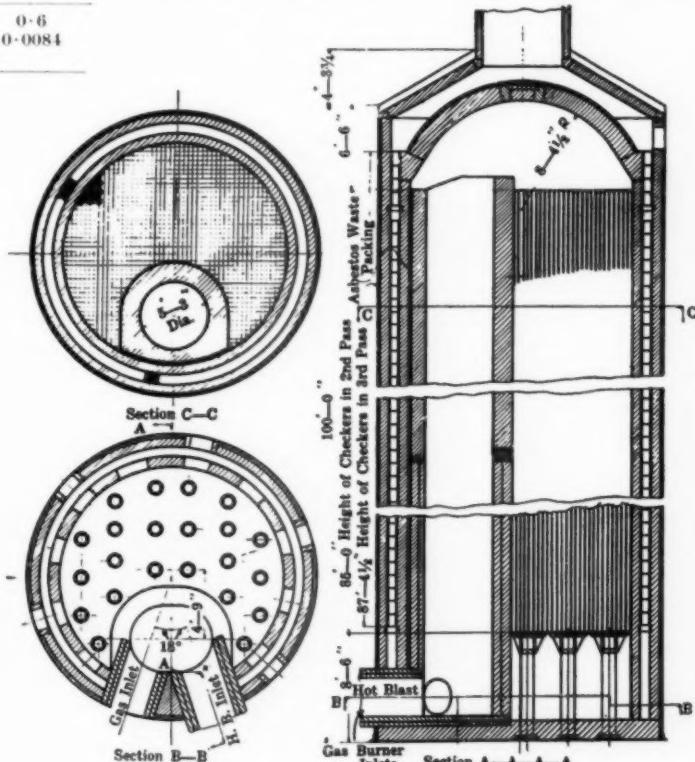

Plan and elevation views of hot blast stove, showing support for checkers.

the fuel practices in the plants under consideration, and the cost of producer gas or other fuels which it is expected to supplant with mixed gases ; the cost of buying or producing electric power ; and, finally, the cost and practicability of constructing the cleaning and distributing system.

In general, however, it may be stated that where there is no domestic market for coke-oven gas, any steel plant having two or more blast furnaces and by-product coking capacity sufficient for its needs cannot afford to overlook what, in many cases, will prove to be a highly profitable means of reducing costs, increasing output, and improving the quality of product.

THE C.P. HICYCLE SCALING OUTFIT.

PORTABLE electric tools have been brought to a very high degree of efficiency and utility. In comparison with pneumatic tools, those driven by the usual industrial electric supply show up badly in point of weight, and no matter how ingenious the design or how carefully useless material is eliminated, there is still the necessity for a mass of iron to form the magnetic circuit of the motor. There is no doubt that a portable electric tool is exceedingly economical, the convenience of being able to plug into the electric supply mains at any point is very great, and they would certainly be used to a greater extent if lighter to handle and without risk of overloading and burning out the windings.
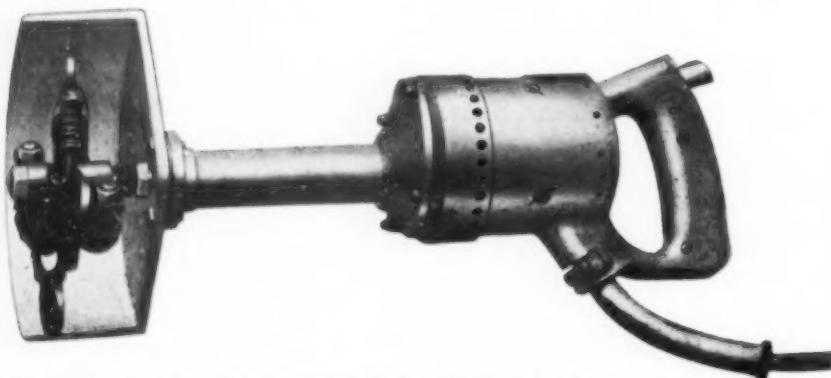
A system has been developed which removes these objections. It is known as the Hicycle Electric Tool, and, power for power, it is only about half the weight of the usual electric drill or grinder. As is well known, the speed of an alternating current induction motor is governed by the frequency of the supply, and with the standard 50 periods it is not possible to obtain a greater speed than 3,000 r.p.m. If this frequency is doubled, 6,000 r.p.m. can be obtained, and, broadly speaking, the horse-power would be doubled for the same weight of material in the machine. If the frequency is again doubled, which is what is done in the Hicycle system, the tool is more efficient, and an immense power becomes available in a hand-tool. The desired working speed is easily obtained by suitable reduction gear.

The high frequency solves the problem of overload troubles, as the self-induction of the motor windings at high frequency is so great that, even should the rotor be absolutely stopped for a short period the rise of current will not harm the stator windings.

The C.P. Hicycle rotary electric scaling tool, shown in the accompanying illustration, carries a patented type of head suitable for medium and fairly heavy scale usually encountered on ships' hulls and decks, and structural steelwork of some age. The tool consists of a helix of stout steel rod, upon which are mounted four loose strikers of high-grade alloy steel specially heat-treated to give an intensely hard-working face, with a tempered shank to prevent any chance of fracture. The strikers are separated by a special arrangement of springs, which are most effective in absorbing the reaction after each blow, and steadying the striker in readiness for the next. The circular shape of these little hammers, coupled with the fact that they cannot strike other than a glancing blow, ensures no cutting action or damage to the metal underlying the scale.

Various heads can be fixed to suit the nature of the scaling to be done, and the renewal costs are negligible in comparison with the economics obtained by the use of these tools. A comprehensive range of drills, reamers, grinders, screwdrivers, nut-runners, surfacing tools, etc., have been developed in connection with this Hicycle tool, made by the Consolidated Pneumatic Tool Co., Ltd.

RESEARCH WORK.

IT is now fully recognised that in executing its functions of dealing with fundamental problems, the prime concern of a Research Department is the observation, study, and development of scientific advancement with a view to its industrial application. In addition to pioneer work of this kind, the important function of serving the immediate needs of the design and manufacturing departments must not be overlooked. This often involves much investigational work into difficulties and problems of all kinds, and a close technical surveillance of materials and processes utilised in manufacture. Such work has been carried out continuously at the Trafford Park works of Metropolitan-Vickers, with the most beneficial results. An example of work undertaken in connection with problems of design and manufacture of standard apparatus is an investigation into the gradual deformation of metals under conditions of high temperature and stress. Investigational work has been carried out on the permanent distortion or " creep " of steel, and recently an important addition has been made to the test equipment which enables the creep characteristics of any steel to be compared immediately with a standard at any temperature up to 800° C., thus effecting a great saving in time necessary for testing.

Investigational work on the subject of creep has advanced in two new directions. The first of these is the study of strain rates sufficiently low to represent the actual conditions which can be tolerated in turbine construction. The second line is the consideration of the effect of compound stresses on the creep of metals. Two combinations of straining actions have been studied in their application to thin-walled tubes, one combination consisting of tension with torsion, and the other consisting of internal pressure with superimposed axial load, the latter tests being carried out with lead tubes. The tests on steel and lead have given results in agreement as to the axial and circumferential creep of cylindrical parts under internal pressure. A further result of the work has been the discovery that the structural changes which occur in carbon steels at high temperatures may also take place in some form at the working temperatures of present turbine practice. The whole investigation has clearly established that even at the lower temperatures and stresses of turbine practice, steels must no longer be regarded as permanent and elastic materials. In future, the design of plant must take into account a rate of creep or permanent distortion consisting of a tensile strain of the order of 10^{-8}.

PATENT SPRING ANCHOR CLIP.

The patent anchor-clip device, which is supplied in a variety of forms, is an important development in design, due to Messrs. Samuel Fox and Co., Ltd. The purpose of this device is to distribute the stresses of braking torque reactions through those portions of the spring which otherwise become idle under torque reaction conditions. The adoption of the Fox Anchor Clip ensures a means whereby under braking conditions the torque reaction is distributed through as many spring leaves as is considered desirable. It can be fitted to any existing type of spring, provided the dumb iron and shackle clearances will permit of the extra plate thickness, and in any circumstances could be adopted without serious alteration to dumb iron or shackle design. The arrangement of the anchor clip can, of course, also be used as a means of limiting rebound, and should on all these points find a ready market amongst vehicle builders.

METALLURGIA

The British Journal of Metals.

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PRINCIPAL CONTENTS IN THIS ISSUE:

METALLURGIA
THE BRITISH JOURNAL OF METALS.

1929.

JANUARY is a month of stocktaking. It is customary for us almost to regard each year as a distinct and definite period and to draw up a balance-sheet of the past year's work and results, comparing it with the two or three years preceding it, and this mental attitude has a distinct economic value because it gives an impulse to commercial and industrial enterprise. The year 1929 was commented upon in certain sections of the daily press as though it had been the blackest year in our industrial history, but in certain important respects, while trade depression was acute, there was evidence that British industry was again on the upgrade after about ten years of unprecedented depression. Especially was this the case in regard to what may be generically termed the iron and steel and metal industries. No reasoning person would aver that there was much occasion for rejoicing, or that there were any indications whatever that a boom period was approaching, but it is undeniable that, in the markets of the world, British commerce again began to make itself seriously felt, and the pessimism that for several years had been a deadening influence was gradually replaced by a spirit of optimism ; in other words, instead of advertising to the world that this country was a bankrupt nation, a serious endeavour was made to prove that Britain could and would regain its old industrial supremacy. Engineering, for instance, may be termed our pivotal industry, and throughout the twelve months progress towards recovery, whilst slow, was steady and continuous. Machine tool makers experienced an increasing demand both in home and overseas markets, while for constructional steel work and bridge building more business was obtained than during any one of several previous years. Substantial contracts were obtained from home and overseas railways, and heavy electrical concerns maintained their comparatively prosperous condition. Shipbuilders took a considerable amount of tonnage, and on the North-East Coast alone during the twelve months there was the very substantial increase of 54 vessels and 29,728 tons over 1928. During the closing days of the year steel makers were confident of a considerable expansion of business early in 1930, and producers in some of the most important centres had much work in hand. The year's output of steel showed an encouraging increase on the total for 1928, and was the highest for many years.

For some years, as far as this country was concerned, rationalisation was a nebulous idea, little understood even by those who used the term most frequently, and was confused with simple amalgamation. There was thus much opposition to rationalisation of an almost unintelligent kind, but it is accepted now as almost axiomatic that if a large and complex industry is to achieve the fullest possible service to the community it must be rationalised. Rationalisation not only means a reduction of overhead expenditure, but the organising and equipping of an industry for the highest possible production. During the year the physical amalgamation of two of the largest iron and steel companies was accomplished, which marked a logical step in the policy of rationalising the iron and steel industry, and conversations were started between several other big concerns, which in all probability will culminate in a number of other firms losing their separate entities. Any rationalisation scheme or " understanding " that is a basis for a cheaper production of steel must be welcomed.

Rationalisation has for its object the elimination of waste in regard to obsolete plant, inefficient plant, and excessive administration expenses, and, as Sir A. J. Dorman, Bart., said recently, unified control of large resources must be a factor in favour of economical production, and should result in the concentration of orders for the most suitable plants, free interchange of technical and commercial information, and the avoidance of overlapping in selling expenses. Even if our industrial leaders were unsympathetic towards the idea of rationalisation they would be forced to adopt it because, on the Continent and in Germany in particular, industries are being concentrated and consolidated into a few large concerns.

In some respects the history of the steel trade in Britain during 1929 was uneventful, but, while accurate figures for the year are not available at the time of writing, it seems probable that the position of this country in regard to steel production will show an improvement for the year, and we shall again take third place, displacing France, although this country can scarcely compare with the United States, which produces nearly six times the amount of steel that it does, and Germany nearly double the British total. The total imports of iron and steel into Britain in 1928 was 2,712,259 tons, and it is probable that the total for 1929 will show some reduction, while, on the other hand, our exports, which in 1928 totalled 3,902,570 tons, will almost certainly show a slight increase. It seems almost certain that while we are not expanding our outputs at the same rate as competitive nations, headway is being made. Sir A. J. Dorman, in the speech already referred to, made the very encouraging statement that as regards 1930 Dorman Long and Co. had made a good start, and, with the exception of corrugated sheets, had a fair order book, while prospects were good in most departments, and expressed the belief that there might be a heavy buying movement before the end of this year. What has been said about the iron and steel industry is also true with regard to non-ferrous metals, although the makers for the non-ferrous metals were probably less stable during 1929 than the iron and steel makers.

IMPORTANT ANNOUNCEMENT.

In addition to many other interesting features, to appear in forthcoming issues, we shall publish a series of articles on The Modern Blast Furnace and Its Operation, by an Authority.

═══1930.═══

We take this opportunity of conveying to the various interests served by this Journal our best wishes for a prosperous year.

Diesel Developments in Germany.

THE recent announcement that the German 10,000-ton battleship, *Ersatz Preussen*, will be equipped with Diesel engines that will have a weight of about 50 lb. per b.h.p. is fraught with interest. It is not known yet whether the credit is due mainly to the engineer or the metallurgist, but it is probable that honours are equally divided. Since the first Diesel engine was constructed some thirty years ago not only the engineers of the Maschinenfabrik Augsburg Nürnberg, who were responsible for it, but those of every firm on the Continent and in this country who have given attention to heavy oil-engine design, have strenuously and continuously endeavoured to reduce the weight per horse-power, as this has been one of the chief objections to the more general adoption of the oil engine for ship propulsion. It seems fitting that the light-weight—relatively—Diesel should have been evolved by the same firm that made the first engine of this type. There are enthusiasts who still believe that the heavy-oil engine will, in the future, eclipse all other types of power-movers for marine work, but it is undeniable that the promise of twenty years has not been fulfilled, and even if the weight objection were overcome it is improbable that oil engines would be installed in many passenger liners, although they would have a considerable sphere of usefulness for cargo-carrying vessels. The oil engine is likely to have a formidable competitor in the electric method of propulsion, because of the latter's greater flexibility of control.

The engineer has endeavoured with more or less success to gear down Diesel engines to an efficient propeller speed, because fast running reduces weight of the engine, although the weight of the reducing gears has to be taken into consideration. As secrecy is naturally being observed by the designers of the *Ersatz Preussen*, there may be modifications of design of quite an exceptional kind that have accounted for the low weight per horse-power, but the research laboratory of the M.A.N. have no doubt devoted much attention to the adoption of metals and alloys which would combine the maximum of strength with the minimum of weight. The conditions were extraordinary, and such as would stimulate the ingenuity of both engineers and metallurgists, because the displacement of German warships is strictly regulated under the Treaty of Versailles, and it is quite likely that the new battleship will be a more effective weapon of destruction than those built by rival powers of nearly double her tonnage.

From a metallurgical point of view, Diesel engines have had an eventful history. In the early period, cracked liners and pistons were common, temperature conditions being the principal cause. It was soon evident that slight flaws or imperfections that would have been of little importance in ordinary castings would be fatal in a casting for an oil engine. It is of interest to recollect that at the conference on Diesel-engine castings held at Glasgow between the Institution of Mechanical Engineers and the Institute of British Foundrymen a few years ago, comment was made on the fact that British practice demands more even thicknesses of material than Continental practice, and it was stated that sufficiently hard metal could not be obtained on the inside of cylinders made in this country with the Continental design, so that the designer was faced with providing for an extra weight of 33%, or an extra cost of not less than 100%; this was an engineer's point of view, and not fair to British foundries, that can produce castings equally as good as any produced on the Continent. It would be of interest to know to what extent

steel has been used by the Germans to reduce weight and corresponding reduction of the temperature stresses, and also whether aluminium has been employed to a greater extent than formerly.

Forthcoming Meetings

THE INSTITUTION OF MECHANICAL ENGINEERS.

Jan. 24.   General meeting. Sixth Report of the Steam Nozzle Research Committee.

JUNIOR INSTITUTION OF ENGINEERS.

Jan. 24.   "Refractories for Steam-raising Furnaces," by W. J. Rees, B.Sc., F.I.C., of Sheffield University (slides and exhibits). 39, Victoria Street, S.W. 1.

Jan. 31.   "Superheating," by F. Onions, Wh. Ex. (Illustrated by film). 39, Victoria Street, S.W. 1.

INSTITUTE OF METALS.

Jan. 16.   "Modern Annealing Furnaces," by J. Fallon, Birmingham Section.

Feb. 4.   "Nickel Casting Alloys," by John McNeill, A.R.T.C., Birmingham Section.

Feb. 10.   "Pyrometry," by S. J. Hawkins, Scottish Section.

Feb. 11.   "Electric Heating," by W. Richardson, B.Sc.

Feb. 12.   "The Corrosion of Non-Ferrous Alloys," by A. G. Ramsay, Ph.D., B.Sc., A.I.C., Swansea Section.

Feb. 13.   "Temperature, Measurement and Control in Works," by H. H. Smith, London Section.

Feb. 14.   "Recent Developments in Measuring Instruments," by S. Matthews, B.Sc., Sheffield Section.

INSTITUTE OF BRITISH FOUNDRYMEN.

Jan. 16.   "High Duty Grey Cast Iron," by A. E. MacRae Smith, London Branch.

Jan. 18.   "Fifty Years of Practical Foundry Life," by P. Macfarlane, Scottish Branch.

Jan. 25.   "Some Interesting Moulding Jobs," by E. Longden. Birmingham Branch.

Jan. 25.   "Is Technical Education of worth to Foundrymen?" by W. H. Meadowcroft, Middlesbrough Branch.

       Joint Meeting with Newcastle Branch at West Hartlepool.

Feb. 1.   General Discussion on Foundry Problems. Official Visit of President of the Institute. Mr. Wesley Lambert. West Riding of Yorkshire Branch.

Feb. 8.   "Steel Castings," by T. M. Service. Scottish Branch.

Feb. 11.   "Foundry Coke," by S. E. Robinson, Lancashire Branch.

Feb. 14.   "Non-Ferrous Castings from a Metallurgist's Point of View," by J. E. Newson, M.Met., Middlesbrough Branch.

Feb. 15.   "The Physical Properties of Foundry Coke," by Prof. H. V. A. Briscoe, D.Sc., East Midlands Branch.

Feb. 15.   "The Influence of the Constitution of Cast Iron upon its Uses," by R. Hay, Ph.D., B.Sc., A.I.C., Falkirk Section of Scottish Branch.

Feb. 15.   Discussion: "The Training of Apprentices," opened by W. R. D. Jones, Wales and Monmouth Branch.

INSTITUTION OF WELDING ENGINEERS.

Jan. 30.   "Modern Improvements in Resistance Welding Machines," by C. A. Hadley, at Birmingham.

Correspondence.

To the Editor, METALLURGIA.

Sir,—I am interested in aluminium bronze, and believe that the possibilities of this alloy are not yet fully realised. Can you inform me whether any research work has been carried out with a view to determining its acid-resistance qualities? I was interested in the work of Dr. Hatfield on " Acid-Resisting Steels," published in your November issue. Similar work on aluminium bronze would be very helpful, and I would appreciate any information you can give that would assist me in my search for particulars.— Yours faithfully, D. R.

[In reply to D. R., we have no knowledge of any research work on the acid-resisting qualities of aluminium bronze carried out in this country, but some assistance may be obtained from the eighth report of the Alloys Research Committee of the Institution of Mechanical Engineers, on the properties of " Alloys of Aluminium and Copper," by H. C. H. Carpenter and C. A. Edwards (1907). The ninth report of the same Committee considers the properties of some " Alloys of Copper, Aluminium and Manganese," by W. Rosenhain and F. C. A. Lantsberry (1910), with which is an appendix on " Corrosion of Alloys of Copper and Aluminium " when exposed to the sea. Reference to acid-resisting qualities is made in a book entitled " Corrosion : Causes and Prevention : an Engineering Problem," by F. N. Speller, and published by the McGraw-Hill Book Co., 6, Bouverie Street, London, E.C. 4. (1926). Price 30s. net. On page 483 of this work is given a table of the relative corrosion of metals and alloys in various acids. The average penetration in inches per year of aluminium bronze is given as follows :—

Normal hydrochloric acid	0·008
Concentrated hydrochloric acid	0·044
Normal nitric acid	0·44
32% nitric acid	10·88
Normal sulphuric acid	0·006
10% sulphuric acid	0·004

We would also refer our reader to W. M. Corse's paper on " Aluminium Bronze : An Acid-resisting Material," in the " Transactions of the American Society of Steel Treating," vol. 10 (1926), p. 898. In this it is stated that aluminium bronze is only slightly affected by concentrations of sulphuric acid up to 75%, and of cold hydrochloric acid up to 5%. It should, however, only be used with cold acids.— EDITOR.]

To the Editor, METALLURGIA.

Dear Sir,—As a matter of interest, I should like to refer to page 46 of the current issue of METALLURGIA. In the second column mention is made of two steels of the following compositions : C. 0·35, Ni 3·5, Cr. 1·5, etc., and Ni 1·25, Cr. 0·65, etc. These are said to be corrosion-resisting steels, but it would seem that this is in error. Doubtless these two steels resist corrosion better than carbon steel, but they are very different in this respect from the high chromium stainless steel mentioned. Actually, the first is an air-hardening Ni Cr steel, whilst the second is an oil-hardening Ni Cr steel. Both are commonly used where high strength and ductility are required, but I have never heard of them being employed for their corrosion-resisting properties. My own experience suggests that they have little to recommend them in this respect.—Yours faithfully,

K. NAPIER.

To the Editor, METALLURGIA.

Dear Sir,—In reply to K. Napier's letter, referring to the nickel-chrome steels mentioned in the December issue of your journal, may I state that a typical analysis of a stainless steel was given containing 10·44% chromium. This steel, as your correspondent will be aware, has only moderate strength, but high resistance to corrosion. For increased strength and greater reliability under exacting conditions the nickel-chrome steel alloys are used, but their corrosion-resistance properties are reduced with the reduction in chromium content. In regard to steels for aircraft purposes, the resistance to corrosion is not less important than the resistance to varying stresses to which they are subjected, and this accounts for the emphasis given to corrosive-resistance properties. The progress of chromium plating as a protection against corrosion is simplifying the solution of the problem of combining strength and corrosion-resisting qualities in the base metal. Thanking you for the opportunity of replying.—Yours faithfully,

SPECIAL CONTRIBUTOR.

To the Editor, METALLURGIA.

Sir,—The depression in the steel industry has now lasted for seven years, and during this period its production has averaged about 60% only of its capacity. Under these conditions the demand for rolling-mill plant has been almost non-existent, but with the need for repairs and renewals naturally increasing as time has gone on.

During the first half of the past year there was some improvement in the production of steel—namely, about 10% over the previous year's average, and almost concurrently the demand for rolling-mill machinery showed some improvement. Unfortunately, however, during the past few months there have been several factors which have adversely affected the situation very seriously.

The two most important items affecting the cost of steel are taxes and fuel. Under present conditions taxation on the average represents 20% of the cost of production of steel, and fuel represents 35%.

The legislation which is at present actually under contemplation would have the effect of materially increasing taxation, and the anticipated coal legislation would have the effect of raising the price of coal, handicapping further the steel industry.

The combined effect of these conditions has been to weaken confidence, and cause a distinct check to the slight improvement in the demand for rolling-mill plant and other steel-works machinery that was manifesting itself six months ago.—Yours faithfully,

A. J. CAPRON,
Managing Director of Davy Brothers, Ltd.

To the Editor, METALLURGIA.

Dear Sir,—I venture to make the following suggestion to the readers of your valuable publication. To those who are members of the Iron and Steel Institute, I suggest they obtain at least one new member for the Institute during the coming year. To those not yet members, I invite them to take up membership with the utmost despatch.

The Institute has laboured long and arduously for the benefit of both the iron and steel manufacturers *and* the users, but for the benefit of prospective members some advantages arising out of membership should be stated. The Institute is bound by its constitution to hold at least two principal meetings in the year, and the Council may authorise further meetings to be arranged. Last year, in addition to the general meetings in London and Newcastle, meetings were held in Glasgow, Sheffield, Scunthorpe, and Birmingham. The reading and discussion of papers at these meetings is an important part of the proceedings, but there is another aspect of these functions : members have an opportunity to " get together " and discuss their own troubles and difficulties.

Another asset of membership is the Library of the Institute, which is claimed to have the finest specialised collection of literature on iron and steel technology and allied subjects in the Kingdom. Members may consult text-books, volumes, and periodicals in the reading-room, or may borrow them on the simplest of conditions. A " library service " is in operation, and the number of requests for information and for references to the literature on the most varied subjects is steadily increasing. An increase of members will augment the resources of the Institute and enable it to become of even greater assistance to the industries than it has been in the past.—Yours faithfully, G. C. LLOYD, Secretary.

Common Errors in Steel-Making

By Walter Lister.

Part II.

Working Down.

AN ACID CHARGE.

AN acid charge should never be fed until the bath is clear melted. Many melters, anxious to gain a little time, will commence feeding while there is still some scrap undissolved. This is a mistake, as it results in frothing up the slag and over-oxidising the bath. This condition lasts for quite a considerable time, during which no further feeding can take place ; so that in the end more time is lost than gained, to say nothing of the inferior quality of the ultimate product.

In acid working, all efforts should be concentrated on quality ; production should be only a secondary consideration. For this reason, no attempt should be made to break any records in feeding down. For a 25/30-ton furnace (which is the usual acid size) no more than ten shovelfuls of lumpy ore should be given each time, and this should be allowed to work off and the bath to become clear again before another feed is given. Failure to observe this results in difficulty in catching the carbon for tapping, as probably at the end the carbon will drop too quickly to ensure the cast being within specification. Moreover, the bath will not be entirely de-oxidised, and much of the finishings will be lost in consequence. The ultimate analysis of the pit sample will show rather surprising results, not in the least as per calculation, all the elements, except perhaps sulphur, being on the low side. If, for any reason, the bath *has* become unavoidably over-oxidised, about 10 cwt. of siliceous pig iron should be put on the doors and allowed to melt into the bath. After this a last analysis of the bath should be taken before adding the finishings.

An oxidised bath will show blow-holes in the sample, but the presence of blow-holes does not always indicate over-oxidation : they may also be formed by a reduction of silicon from the slag. The two can easily be distinguished one from the other by observing the inner surfaces. In an oxidised bath the inner surfaces of the blow-holes will be black while those due to a reduction of silicon will be bright and clean. It is towards the end of the process when a reduction of silicon takes place. It is due to an excess of silica in the slag, which will now be very thick. The addition of a few shovelfuls of limestone now combines with the excess silica, and the blow-holes in the samples disappear. Also, the slag becomes more fluid and easier to tap out.

There are many acid melters who think that the addition of limestone is simply to thin out the slag. They therefore leave this until the last minute or so before tapping. This does not give it time to do its work in the matter of the blow-holes, which will, in consequence, probably appear in the ingots. About 2 cwt. of limestone should be added through the end doors as soon as the silicon blow-holes appear, which may be half an hour or so before the carbon gets down to the going-on point. About 2 cwt. more can be added if the slag thickens up again after the finishings are put in. An acid charge should be tapped while the bath is completely " dead." It is a mistake to allow it to come on to a boil again, after the finishings are put in, as not only will some of the finishings be lost, but the ingots will probably be honeycombed.

BASIC COLD CHARGE.

Unlike the acid, a basic cold charge, unless wanted for a very high carbon, like file steel, should come on the boil as soon as melted. If there is a large amount of phosphorus in the charge, sufficient lime should have been put in to make a thick heavy slag. Under this slag the bath should be boiling, not openly, but sluggishly, as though struggling

to break through. In this condition a lot of phosphorus will be eliminated, while the bath is at a comparatively low temperature, and as much use should be made of this state as possible. It is a mistake to open it out too soon with fluorspar. A feed of mill scale or iron ore is better, as the phosphorus in the steel requires to be oxidised first before it can combine with the lime.

But the next step should be to open out the slag with fluorspar, because sulphur is more easily eliminated while the carbon is still high, and, for the elimination of this element, it is necessary to open out the slag and allow the bath to boil freely. When boiling, the charge will generate more heat, and a good heat is essential to the elimination of sulphur. No more scale or ore should be added here until the sulphur shows a considerable reduction on analysis of the bath sample. To get the best elimination of sulphur, the bath should be alternately thickened up with lime and opened out again with fluorspar, at the same time keeping as much heat on the furnace as possible. The chimney damper should be lifted a little so that the gas passes quickly through the furnace. It is a mistake to expect the same treatment to eliminate both phosphorus and sulphur.

Phosphorus requires an oxidising action, while sulphur requires exactly the opposite—a reducing action : so that an atmosphere as little oxidising as possible should be maintained until the sulphur is low enough, or nearly so. Then more oxidising materials should be added to get out the remainder of the phosphorus. The following equations will show the reactions necessary for the two elements :—

<center>PHOSPHORUS.</center>

$$\left. \begin{array}{rcl} P2 \; + \; O5 & = & P2O5 \\ P2O5 \; + \; 4CaO & = & 4CaO.P2O5 \end{array} \right\} \text{Oxidising action.}$$

<center>SULPHUR.</center>

$$FeS \; + \; C \; + \; CaO \; = \; Co \; + \; Fe \; + \; Cas \quad \text{Reducing action.}$$
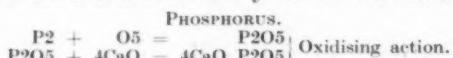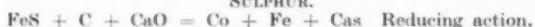
I am afraid that many steelmakers either ignore or are ignorant of these two reactions, and they waste much time and material by adopting a sort of one-treatment process which can only result in increasing the dimensions of the scrap heap.

Some firms find it very difficult to make basic steel suitable for heavy forgings. I think the trouble lies in the fact that their steelmakers carry a slag which is too thin, and, secondly, they do not sufficiently de-oxidise *in the furnace* before tapping. No good steel is ever made with a thin slag. Slag can be thick, but still fluid. If there is not a good covering of slag on the bath the steel becomes *burnt*, just as much as the ingot may be burnt in a re-heating furnace, and burnt steel is always weak steel, and will not stand any forging operation without developing surface cracks. All steel should be made in the furnace, and not in the ladle.

Some steelmakers seem to think that for basic steel it is quite sufficient to add various physics to the ladle as the charge is running out. But this is not so, and the man who depends on this alone will never make good basic steel. It is possible to de-oxidise a basic bath with ordinary pig iron alone, throwing in a few hundredweights at intervals as the carbon comes near the tapping point : but a much quicker and safer way is to use 10% silicon pig. When this boils through the bath will be comparatively free from dissolved oxides, a condition which can be noticed in the bath samples. In addition to the silicon pig, half the manganese required should always be added to the bath before tapping, either in the form of ferro-manganese, spiegeleisen, or silico-spiegel. In the case of the latter, about 75% of the silicon content should be expected to appear in the finished steel.

In no open-hearth charge should the furnace be overheated to such an extent that the brickwork begins to run. But it is surprising how often this happens. Any steelmaker who habitually does this is not worth his job. I admit that for some classes of steel, such as soft tube steel, where specially low sulphur is required, more heat is necessary than for other classes, but even in this case it is an unforgivable sin to burn the furnace. At one particular works I know of, the manufacture of tube steel is always attended by a woeful record of dropped roofs and stalagmitical port ends. At another works, I have heard of three new roofs being put on the same furnace in as many weeks—and tube steel was *not* being made there either. This sort of thing must quickly eat up all the profits, and leave a balance well on the wrong side. The pity of it is, it is totally unnecessary. Enough heat can be got on any charge for any purpose without endangering the brickwork.

As soon as the port-ends are seen to be near the melting point the gas should be reversed immediately and the air-screw dropped. After, say, two minutes' interval, the gas and air should be reversed again. This usually has the effect of cooling the furnace down sufficiently. Naturally, if the furnace is dangerously near the fusion point, there is too much gas, and this should be regulated accordingly. Usually, if the end of the flame does not quite reach the port end, there is no danger of over-heating. Peep-holes in the end doors are very useful contrivances for watching the gas as the flame is not disturbed, as is the case when the entire door is lifted.

BASIC HOT CHARGE.

A basic charge of 100% hot metal should come on to boil about three hours after being charged. But it should never be allowed to boil with the old slag on. If this happens for any length of time, a lot of the good work done during the melting period will be wasted, as phosphorus will go back from the slag into the steel. When the old slag has all been run off and a new one made, then, and only then, should the bath be encouraged to boil freely. As the bath will still be highly oxidised, it should be allowed to boil for some time without any further additions of iron ore or mill scale. This is a very important point in the working of a hot-metal charge, and one which is often overlooked by many steelmakers. It is hopeless to expect any elimination of sulphur until the bath gets rid of some of its dissolved oxygen, and any further additions of oxidising agents at this period only tend to increase the sulphur content of the bath rather than diminish it. Fluorspar should be added freely with the new slag. The phosphorus will be noticed to come down rapidly for a time and then stick. The bath will now be de-oxidised, or nearly so, and some elimination of sulphur may be expected. Further additions of lime and fluorspar should be made, but no oxidising material whatever until the sulphur is within limits. Then the remainder of the phosphorus can be oxidised out and the carbon worked down to specification.

The Talbot process is one in which it is difficult to eliminate sulphur unless suitable precautions on the lines I have indicated above are taken. In cast after cast made by this process it can be seen that the sulphur in the finished steel is higher than that originally in the mixer iron. This is because the bath is so highly oxidised right through the working; and, in the routine as usually carried out at some works, there is no period in which it is allowed to get rid of its dissolved oxygen and so produce conditions favourable to the elimination of sulphur.

It is this routine business which is chiefly to blame; the men are not allowed to be steelmakers, but degenerate, and become simply melters. Quite as good steel can be made by the Talbot process as any other if a little more regard is paid to the necessity for a de-oxidising period in which to eliminate sulphur.

In using fluorspar in any basic process, it should always be analysed before use, as, in my experience, I have often found it to contain sulphur. In some samples sulphur can be seen, not only as the black sulphide of lead (galena), but also in the form of a pale yellow crystal.

BASIC ELECTRIC CHARGE.

The majority of basic electric charges are melted dead soft, and have consequently to be re-carburised if a high-carbon steel is required. The material used for re-carburising is usually fine anthracite coal or coke. But it is a mistake to try to re-carburise with this material without the previous addition of ferro-silicon to the bath. The bath, after melting, is so highly oxidised that without this precaution much of the coal or coke is ineffective, a much longer time is necessary for its absorbtion, and usually the degree of re-carburisation is insufficient. A few lumps of ferro-silicon thrown into the bath before the coal is put on will induce a more rapid and complete absorption of the coal, and will further expedite the process.

After the refining slag is made it is a mistake to allow it to become black through over-additions of coal, as this induces a gaseous condition in the steel, somewhat similar to that produced by the reduction of silicon from the slag in an acid open-hearth furnace. The slag should go from the black oxidised stage, through the white, and finally just a dark grey, with a faint smell of calcium carbide when the slag is plunged into water. Moreover, a black carbide slag will cause an unexpected increase of carbon in the finished steel when the slag intermixes with the steel on tapping. And this intermixing of the slag with the steel in the ladle should be avoided, as it can only do the steel harm. Slag inclusions being one of the principal causes of
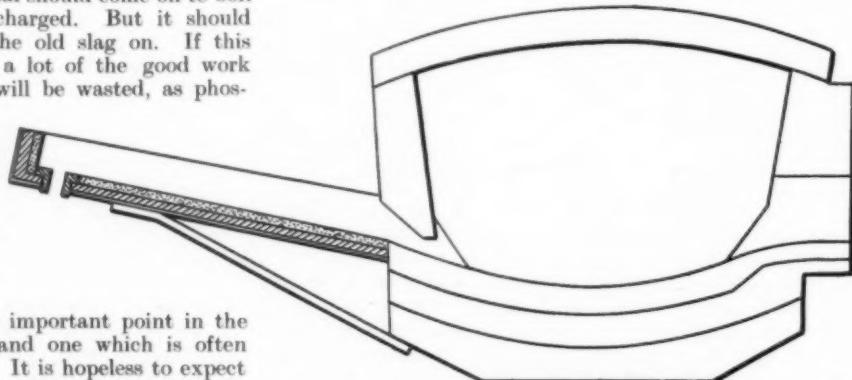
failure in otherwise perfectly good steel, everything possible should be done to keep slag out.

As far as I know, no attempt has yet been made to do this, but I see no reason why a lander on the lines shown in the accompanying sketch should not be utilised for this purpose. As will be seen, the end of the lander is closed, and a nozzle-pot fitted through which the charge runs in a perpendicular stream. The slag is retained on top of the steel which flows underneath. It is only when the steel has all run out and filled the ladle that the slag enters and forms a layer on top of the steel. I know this to be a practical success, as I have worked a basic open-hearth tilting furnace fitted with this type of lander, and the results were perfectly satisfactory.

Electric steel is often overheated; probably more so than is possible in any open-hearth process. When this happens, silica rains down from the roof and side walls, with the result that what was a minute or two ago a good thick carbide slag is now a thin black oxidised slag. Steel tapped under these conditions cannot be any good, and it will be better to run this slag off entirely and make a fresh one. But the temperature of the furnace should never be allowed to reach this point; the charge is too hot long before this point is reached. A good plan is to put the current on low voltage as soon as the charge is melted. Then, although the operation may take a little longer, there is little danger of burning the furnace. Without this precaution, only men of long experience can correctly judge the temperature and safely carry on with a high voltage.

(To be continued.)

Iron and Steel Foundry Practice

By Ben Shaw.

Part II.

Influence of Constituents of Cast Iron. Grading and Selection of Pig Irons. Characteristics Common to Pig Irons According to District in which they are Produced.

To analyse cast iron is one of the most difficult of tasks. It contains in solution, combination, or in suspension carbon, silicon, manganese, sulphur, and phosphorus. Other elements are also present in varying small quantities, such as copper, nickel, titanium, and arsenic, and, in addition, slags and gases are also involved in the heterogeneous mixture we know as cast iron. Of all the metals to analyse, cast iron gives the most trouble, and necessitates the greatest care to ensure accuracy; in fact, it is questionable if accuracy can be attained, rather should it be to attain a high degree of accuracy; Some foundrymen maintain that cast iron contains inherent qualities in addition to qualities resulting from its components which influence its character. Other factors also have a considerable influence on the quality of the metal—its temperature at the time of pouring, the thickness of metal, and the speed at which it is cooled. Considerable variations are evident in the crystalline structure from metal of the same chemical composition, and its physical qualities will vary accordingly.

Although cast iron may be referred to as the most impure form of iron used commercially, its value is mainly due to this fact. The more important of the elements in its composition render it more readily fusible, and give it great fluidity at a temperature lower than that for steel. It is the relative quantities of these elements and the character of their composition that influences the physical qualities of cast iron and renders this metal so complex in character. The chemical analysis of cast iron, while giving a close approximation of the relative content in the composition, does not necessarily determine compounds formed by the elements or the condition in which the elements are present, and some form of physical test is advisable to supplement chemical analysis, in order that its quality for a specific purpose may be determined. A brief reference to the influence of the various elements present is advisable in order that suitable selection of pig iron can be made from their chemical composition and characteristics.

INFLUENCE OF CARBON.

Carbon is the essential element, and the condition in which it is present is an important factor in determining the usefulness of the iron. It may be present wholly as flaky graphite, indicating soft cast iron, which is deficient in strength, has high fluidity, and is easily machined. The graphite may be almost wholly present in a very fine condition, characteristic of stronger irons. With an increasing percentage of carbon present in a combined state the iron becomes hard, is less easily machined, offers less resistance to shock, and solidifies more readily. The design of a casting, and the conditions under which it is cast, in addition to other elements or compounds in the iron, influence the character of the carbon content.

As far as pig iron is concerned, this element is derived from the fuel through the decomposition of carbon monoxide, and sometimes carbon dioxide, whereby carbon is deposited on the spongy metal and passes down to the hearth. There is practically no direct control over the amount of carbon in the final pig, although the other elements present and the manipulation of the furnace have some influence. Generally, hot working produces silicious irons which are high in carbon; on the other hand, cold-blast irons are low in carbon.

Relatively few pig irons are low in carbon, and it would be difficult to maintain their low carbon content in passing through the cupola, where some would certainly be absorbed. When castings are required to be very strong the carbon content should be low, and while difficulties must be overcome to obtain low carbon iron when pig irons of low carbon have been charged, there is a possibility of getting the metal desired, whereas there can be none if high-carbon pig iron has been charged. The carbon content in the metal charged is frequently lowered by using steel scrap, but carbon will be absorbed in the cupola though the resultant metal will have a lower carbon content than the pig iron originally charged if the cupola is operated with care.

INFLUENCE OF SILICON.

Of the other elements in cast iron silicon has the most important bearing on the composition. It diminishes the power of the iron for absorbing carbon, and thus may be said to promote graphitic carbon. It reduces the liability of the metal to chill as the percentage is increased. Generally, it can be assumed that a low silicon contains more carbon in a combined state, whereas a high silicon iron is soft and the carbon present as graphite. Within limits, silicon increases the fluidity of the iron, because of its influence on the carbon, and this enables the iron to free itself better from blowholes and dirt. It opens the texture of the iron, and the strength diminishes with an increase up to about 3%. For high strength the silicon content should be about $1 \cdot 7\%$, but this depends also upon the condition of the carbon. The influence of silicon is such that grading of pig iron is sometimes briefly referred to as " grading by silicon." It is a very unreliable element in pig iron, although the analysis of various brands are remarkably regular, considering the crude material used and the manner in which the blast furnace is operated. The effect of the silicon on carbon is considerably influenced by the sectional thickness of metal: thin sections can carry a higher percentage in their composition and yet have toughness and strength; thick sections, on the other hand, will need a lower percentage to give a similar result. In making up a mixture for the cupola, allowance must be made for loss, and 10% of a desired silicon content should be added in the charge.

INFLUENCE OF PHOSPHORUS.

The special value of phosphorus as a constituent concerns the degree of fluidity it imparts to the metal. This it increases, rendering the iron very fluid and capable of filling the most intricate moulds. It has the power of causing the metal to expand at the time of solidification, which is favourable to an accurate definition of intricate shapes. Within limits it is useful for quickening the metal, particularly for thin ornamental work, when strength is not important; for such work the content may be as high as $1 \cdot 5\%$, but for general engineering work it should, as a rule, be under $1 \cdot 0\%$, and when strength combined with toughness is desirable a maximum content of $0 \cdot 6$ to $0 \cdot 7\%$ is advisable. The strength of an iron may be maintained with high phosphorus, but it is relatively weak under shock tests. It is noticeable in connection with this element that it is transferred from the ore to the iron, excepting when the slag is particularly rich in ferrous oxide, a condition of operation not desirable, or, when the phosphorus content of the ore is very high, which would be very unusual. Ores rarely contain more than $1 \cdot 0\%$ of phosphorus, and this is transferred to the iron. Thus, in localities where ores are

used of relatively high phosphorus content, such as Cleveland and Northampton, pig irons are available containing a high percentage of this element. Some makers grade according to phosphorus content, with the remaining elements practically constant.

INFLUENCE OF SULPHUR.

The influence of sulphur upon cast iron is, as a rule, detrimental to its quality, and its content should be kept within very low limits. It thickens the iron and the reduced fluidity makes the iron subject to blowholes, gases being unable to free themselves owing to the condition of the metal. The melting conditions influence the amount of sulphur that may be present. Both in the blast furnace and cupola it is absorbed from the fuel. It is a useful element when chill is required, but in this respect the amount depends upon other elements. A high silicon iron, which retards chill, will chill with an increase of sulphur. This element will produce a degree of shrinkage which will cause cracking in castings of an intricate character, and will reduce the strength of the iron. Operating the cupola at a high temperature assists in keeping the sulphur low, as part is likely to be absorbed by the limestone flux and carried in the slag. But manganese is the most helpful element ; it neutralises the effect of sulphur, and is the most important element for curtailing its bad influence.

INFLUENCE OF MANGANESE.

In addition to controlling the influence of sulphur, manganese promotes the formation of combined carbon, and unless otherwise counteracted tends to the making of white iron. Within certain limits, however, manganese is valuable in cast iron, as it increases its strength. For general work the iron may contain from 0·4 to 0·5%, but as much as 1·0% may be carried in the metal for heavy sectioned work without detriment. In such cases the metal holds its fluidity longer, and the cooling being slower renders the tendency of the manganese to cause chill less effective. In other castings, in which the sections are of medium thickness, the manganese content should not exceed 0·7%, but the percentage of sulphur will have some influence, as, in combining with sulphur, much is carried in the slag. Although percentages of manganese have been referred to, it will be appreciated that the actual amount to obtain maximum benefit will vary with the class of work in hand. It can be higher in heavier castings, and the two directions in which it exerts influence are both indirect— one on sulphur and the other on carbon.

The properties of these various elements are constant, and may be relied upon to give evidence of their presence provided the iron is melted and subsequently cooled normally, and if allowance is made for gains and losses in melting, various compositions can be prepared from a few brands of pig iron when the analysis is known. But it is a peculiar fact that each district in which pig iron is produced is noted for some particular characteristic of its product. Thus, Scotch pig iron has fairly high manganese and relatively low phosphorus (0·6%). In Nottingham, Derby, and Leicester districts they contain medium manganese, reaching as high as 1·0% in some cases, while the phosphorus is between 0·7 and 1·2%. In Cleveland the manganese is lower, about 0·5%, and the phosphorus higher, about 1·3%. The pig iron from Northampton district has very low manganese, about 0·3%, and high phosphorus, about 1·5%. From North Staffordshire district the pig iron has the highest manganese content, and is associated with a rather high phosphorus, between 0·9 and 1·2%. The differences among these various irons are largely due to the different ores used, and also to varying conditions operating inside the furnaces.

It is not possible to classify the various iron-producing areas according to silicon content of their product, because of the uncertainty in the reduction of the silicon and its variation in one furnace, frequently over short intervals of time. Carbon content is also largely beyond control, and is useless as a means of classification. Thus, the more stable elements, like phosphorus, and, to a lesser extent,

manganese, are being used as a means of classifying the brands of pig iron associated with different districts.

The brands of iron from the various districts vary much in their analyses and in their physical characteristics. Thus, Northamptonshire iron is weak, but very fluid, and admirably suited for light and ornamental work ; Cleveland and South Staffs. common iron are a little higher up the scale ; Notts. and Derbyshire give an iron moderately strong and admirably suited for machinery work ; Scotch iron is still stronger, but it is found that fluidity has given place to strength, in fact to such an extent that the Scotch makers of light castings use iron from Cleveland, and even Northamptonshire, in preference to their home product. Strength and fluidity are not commonly found in the same pig iron.

SPECIAL IRONS.

In addition to these wide classes there are on the market a number of " special " irons, often highly recommended for cylinder and other high-pressure work. Some of these are made by admixture of high-class ores, some by a refining process in open-hearth furnaces, and some by melting steel with pig iron in either cupola or open-hearth furnace.

In many foundries the practice of preparing special metal for future work prevails. Various pig irons are charged after the metal for the day's work has been charged, and when the work has been cast up the special or refined metal subsequently passed through the cupola is cast into pig beds. From an economic point of view the value of the practice is difficult to understand, because the cost in operating the cupola will not be far short of 30s. per ton of metal melted. Special irons are available within this total cost which have a guaranteed analysis within very small limits, and of a suitable analysis for a wide variety of purposes.

The value of cold-blast irons is very considerable when strong irons are needed. Its great advantage is its relatively low silicon and carbon content, while both manganese and phosphorus vary from low to medium according to district ; the sulphur content is often high. Hæmatite, which many foundrymen consider to be the most valuable iron in the foundry, is usually high in carbon and manganese with very low phosphorus and sulphur. It is the relative purity of hæmatite which obtains for it support from the foundry, but it is primarily made for steel-making, and as long as the phosphorus and sulphur are very low the steel-maker is not concerned about the carbon content, which is usually high, and this fact is a drawback to its use in the foundry.

GRADING OF PIG IRON.

In view of the influence of the various constituents of cast iron, some form of grading of pig iron becomes essential in order that suitable brands of a particular composition can be stocked from which suitable mixtures can be made to meet normal requirements. Pig irons are, therefore, numbered, the lowest number of a particular brand being, as a rule, the softest and weakest. Further, because of the characteristics already referred to, the grade number is prefixed by the district of production. Thus, Cleveland No. 1, cold-blast, and hæmatite irons differ from common pig irons as also do special pig irons, and consequently are referred to as cold-blast, hæmatite, or special, as the case may be. Special alloying elements may be necessary, or the normal components may require to be increased, and special components like ferro-silicon or ferro-manganese may be used. It is from an assortment of different grading numbers and different brands from which a desired mixture is obtained rather than the adherence to one particular pig iron, and the economical point of view needs consideration when determining the most suitable pig irons to stock for the work likely to be done. The character and quality of available scrap may influence the determination of the brands and grades likely to be most suitable.

Although reference to the influence of the components of cast iron has been brief, sufficient has been stated to arrive

Choice of Raw Materials for Malleable Cast Iron

Part I.

By J. V. Murray.

Malleable Pig Iron.

THE method of choosing raw materials for the manufacture of malleable castings is in many instances to be deplored. The founder is too often in the hands of the traveller, leaving to him the types of iron to be delivered. In other instances repeat orders are sent out for iron, marked " As before." Some ironfounders insist upon mixing two or more irons, hoping, by some fetish, to control the bad iron by mixing with good. Again, others leave it entirely to the melter to put in what he likes. This latter method has some striking successes. He depends upon the " look " of the molten metal having characteristics which tell him whether the iron is hard or soft. In nearly all these cases a bad day comes when many castings are spoiled, or it may be the trouble is not discovered until after annealing has taken place. Then a scapegoat must be found, and too often the blame falls upon someone who has not had the slightest connection with it. A golden rule is to commence the making of malleable by selecting a good and suitable pig iron.

Malleable castings are made from a hematite pig iron or a refined pig iron low in all impurities. These pig irons are smaller in size than the ordinary foundry pig irons, and are easily handled and broken for use. They are made on the West Coast, chiefly from the famous native ores, although a few furnaces on the eastern side market a malleable iron aided by imported ores. Recently, within the last few years, " refined " pig iron has forced itself to the front, and has more than held its own, especially in the Midlands. Briefly, it may be stated that refined iron is made by remelting pig iron, and, by suitable additions to the melt, bringing up the chemical composition to that required, or that which will give the best mechanical tests after annealing.

The selection of a malleable pig iron will depend upon—

1. The method of melting.
2. The size and section of the castings.
3. The chemical composition.
4. The fracture.
5. The scientific control of the melt.

Pot or Crucible Melting.—Although this method is dying out, there is a considerable number of pot furnaces still at work, especially in and about the Midlands. Some firms swear by this method as being the only reliable one, but tests made mechanically reveal little difference in any method of melting. In any case, it is only a matter of time before pot melting will disappear except for experimental or special purposes. Pig iron, as purchased for this type of melting, is of the same composition as the ensuing castings. Some slight purification may take place, due to the loss of silicon.

Cupola Melting.—During the melting operation in the cupola there is usually an entire change of composition. There is a loss of silicon up to 30% of the amount present, and a gain of carbon up to the same amount. There is also a gain of sulphur and a loss of manganese. These losses and gains should be allowed for in the choice of a pig iron.

Air Furnace Melting.—The losses in this case are not so great whilst the gains are *nil*. The carbon and silicon are under control better. Hence, it might be tabled :—

Method of Melting.	Effect upon Elements.	Allowance to be Made for.
Crucible or pot	None	—
Cupola furnace	Great	Loss of Si. Loss of Mn. Gain of sulphur. Gain of carbon.
Air furnace	Slight	Loss of Si, carbon, and Mn.

Size and section of castings : Obviously, between castings the size of a lady's boot buckle and a stamping die of about 4 cwt., 8 in. × 8 in. × 6 in. in section, there is a vast difference, and also a great variety of shapes and sizes occur between.

If the correct iron used for the thin-sectioned buckle should be used to make a heavier-sectioned article like the die, the result would be a grey iron casting. The particular element in these cases is silicon. The small lady's boot buckle should be made from an iron containing about 1·3% silicon, whilst for the larger sized castings a silicon content of 0·3 would suffice. The one would be a white pig iron and the other a grey malleable iron. The silicon content plays a great part in selecting pig iron for malleable.

Chemical Composition.—Should the choice be by chemical composition some security is obtained. Only an elementary knowledge of metallurgy is required. Some ironmasters make composition their speciality, and will advise the types of iron to be used. It is only necessary to know that :—

Silicon : Varies according to section from 0·3% for large articles to 1·3% for very small castings.
Sulphur : About 0·10%, not exceeding 0·30%.
Phosphorus : Under 0·10%, maximum allowance 0·18%.
Manganese : Should be double the sulphur, but not more than 0·6% (according to the method of melting).
Total carbon : About 3·00%. From 2·86% to 3·5%.

By Fracture.—This is a very unwise procedure. The method of casting, pouring, rate of cooling, and many variables enter into this. Whatever the fracture is, it breaks down during any remelt. The writer had a consignment of grey chill-cast pig iron, with silicon varying from 0·65 to 1·58. Yet it was all of a grey fracture. A further consignment of sand-cast grey malleable yielded no different results. The silicon ranged from 0·85 to 1·50. The difference in these irons would ruin a day's work. Fractures of pig irons range from (1) to (5) :—

1. White : No graphitic carbon present.
2. Tic white : A few tics of graphite present.
3. Hard mottled : Slightly grey in centre, white outside.
4. Soft mottled : Larger inside area of greyness, white edges.
5. Grey : All grey ; plenty of graphite present.

Some ironmasters have greater varieties, intermediates coming in between. The writer has had grey-mottled malleable pig of 0·72% silicon, whilst a white iron contained 0·80%. In the former the carbon content was high, whilst in the latter the carbon was low and the sulphur high. Hence, it may be stated that the traditional choice by fracture has broken down. Silicon and carbon tend to make fractures grey, whilst sulphur and manganese keep it white, and if the elements vary, the fracture cannot be controlled unless the constituents of the metal are.

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It is well known that chills will produce a super-cooling effect and give white fractures. Thus, should pig iron be cast in chills the fracture must tend to become white. This whiteness is assisted to form by spraying over with water. Should the mould be warm or hot, the fracture becomes greyer because the super-cooling effect is less. The effect of the chill disappears on remelting. Those who choose pig iron by fracture are well advised to ask for sand-cast pig iron.

By Scientific Control of the Melt.—This involves the setting up of a chemical laboratory, and, by analysis, to control the incoming raw materials and the outgoing castings. In this case it is only necessary to have hard and soft varieties of malleable pig iron and the mixture may be calculated. The castings can be kept within 0.15% silicon. Any mixed consignments can be rejected, and the ordering may be conducted on a special analysis, allowance being made for the blast-furnacemen varieties. The specification may read :—

Type of Iron.	Si.	S.	Ph.	Mn.	Total Carbon.
Hard	0·4 to 0·55	Low	Low	0·3	2·90 to 3·30
Soft	0·80 to 1·00	Low	Low	0·4	3·00 to 3·40

Blast furnaces can easily work within these limits.

It is generally argued that this method is expensive. Whilst arguing that this is the case, on reflection it may be seen that there is also a saving, because given good raw materials there is a better chance of securing good castings and less wasters. Whatever the method of selecting pig irons, it must always be directed towards producing a white iron casting. This will be discussed later.

Characteristics of Pig Iron.—The characteristics of a pig iron are not destroyed during a remelt. The inherent properties of pig iron, though modified by conditions, will persist and exhibit themselves in the castings.

If a pig iron possesses peculiar properties, such as hardness or severe contraction, or even that mysterious and elusive property known as " body," one may reasonably expect these physical states to be present in the casting. It has been said that East Coast and West Coast pig irons do not blend well together, but experience has proved otherwise.

analysis will not reveal any defects, and there are few physical tests for pig irons. Correct blending with irons will lessen these defects.

Whilst the inherent properties of a pig iron are not destroyed during a remelt, the micro-structure is (unless one is using a white pig iron) entirely altered when cast. Only one structure is allowed in the castings for malleable work. Consider the three photo-micrographs. The following analysis gives their compositions :—

Type of Pig.	Si.	S.	P.	Mn.	T.C.	Remarks.
Grey malleable	0·87	0·153	0·053	0·21	3·38	Small sized
W.C. hematite	1·25	0·048	0·031	0·26	3·65	Large ,,
Foundry	3·00	0·022	1·54	1·00	3·40	,, ,,

Figs. 1, 2, and 3 show the unetched structures. The small flaky graphite of the grey malleable may be compared against the long thin plates of the hematite. The reason for the difference may be found in (*a*) increased silicon and carbon, and (*b*) the smaller sections of the pig irons compared. If the foundry pig iron is now noted, it is observed that the graphite is long, thick, and coarse, which denotes weakness. This is due chiefly to the increased silicon content, since both the hematite and the foundry iron are similar in size. It may be deduced that if the silicon content be lowered the size of the graphite is reduced in proportion until, upon continual lowering of silicon, there is no graphite present. Thus, a 0.4% silicon pig iron is white— *i.e.*, no graphite present.

In the etched condition (Figs. 4, 5, and 6) these irons show remarkable differences. In Figs. 4 and 5 the mass of the structure is entirely pearlitic excepting a few small areas of phosphide of iron and manganese sulphide in the grey malleable pig iron, which will be removed when melted. These pearlitic structures give some indication of strength. Pearlitic is always present in sections of malleable castings of a half inch and over. Only the flaky graphite is destroyed. This latter is taken into the solution during the melting, and solidifies as a constituent of a compound known as cementite.

The structure of the foundry iron (Fig. 6) is seen to be long streaks of ferro-silicide (FeSi), large areas of phosphide eutectic, and very little manganese sulphide, although

GREY MALLEABLE PIG IRON.　　　WEST COAST HEMATITE PIG IRON.　　　FOUNDRY PIG IRON.
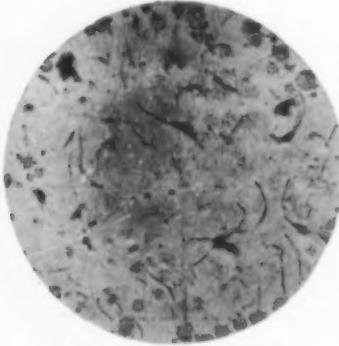
Fig. 1.—Fine Curly Graphite.　　　*Fig. 2.—Thin Platy Graphite.*　　　*Fig. 3.—Long Coarse Graphite.*
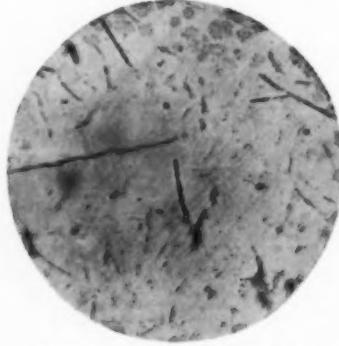
All Unetched × 100.

Certain physical properties are produced by chemical constituents—such as brittleness being due to phosphorus over 0.20%, which is the limit for malleable pig irons. These can be made to disappear by suitable blending with low phosphorus pig irons, but the intrinsic properties are not removed. Castings must be heat-treated correctly to bring them out. Too often is the blame thrown on the pig iron when it should be borne at home. There are times when bad conditions at the blast furnaces will yield bad pig irons. These conditions are mostly due to accidents, or something over which there is no control. Chemical

1.00% manganese is present. Such a structure could not be made malleable. Annealing would make this type of iron rotten. Phosphide eutectic is never allowed to be present. It is plastic at about 950° C., is not removed during the anneal, and the castings would warp. Its presence indicates brittleness. During a remelt the phosphorus is not removed, and if the eutectic is prevented forming by chilling, the phosphorus is seen and is present as phosphide of iron (Fe_3P).

The study of these structures gives some indication as to the reason why the impurities must be kept low. They

are present because they cannot be removed in the blast furnace. By keeping these in their proper amounts, the structures of the pig irons are such as will give the correct micro-constituents to the white iron castings—namely, pearlite and cementite. This structure responds to annealing.

Annealing Ore.—In annealing white heart malleable castings, the raw material is ferric oxide (Fe_2O_3). This should be pure and free from dust or lumps. By purity it is meant that the ore should be low in silica and calcium. Should the ore contain large amounts of these elements

of iron (excess from the white heart) is suitable. Intrinsically, sand and brickbats may be used. Practically speaking, any kind of inert packing may be used, providing they protect the castings from the burning gases. This is properly crushed for use.

Coke.—Price of coke is secondary when the product is malleable castings. These require super-heat for casting. Low-temperature pouring is responsible for many defective castings. The rule is *hot metal* for malleable. Good hard coke of high calorific value and intensity is to be preferred before chemical analysis. Under such conditions, regarding

GREY MALLEABLE PIG IRON.   WEST COAST HEMATITE PIG IRON.   FOUNDRY PIG IRON.
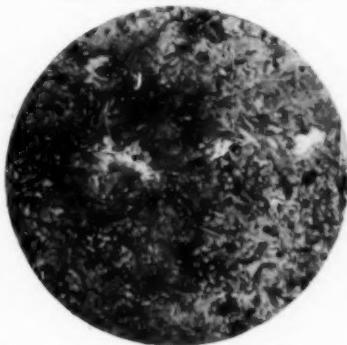
Fig. 4.—*Nearly all Pearlite.*   Fig. 5.—*Nearly all Pearlite.*   Fig. 6.—*Dark zones, Pearlite ; white, long streaks, Ferro Silicide ; half-tone areas, Phosphide Eutectic.*

All Etched in Picric Acid Alcoholic Solution × 100.

there is a tendency for it to partially slag itself to the castings, at the high temperature maintained during the anneal. The castings cannot be removed from the can, or only with difficulty. Even then they are spoiled. The ore should be rich in iron oxide (Fe_2O_3). About 90% of this being present ensures a good supply of oxygen. Should the percentage of ferric oxide be lower, there is a deficiency of oxygen. Lime is not permissible, since it slags with silica and iron oxide, if present in quantity. A good ore has the following approximate analysis :—

Fe_2O_3.	SiO_2.	CaO.	Other Elements.
90·0%	5%	0·5%	4·5%

Magnetic Oxide of Iron.—This is the black ore which has been used during the anneal. Annealing ore is Fe_2O_3, and is red in colour. During annealing it becomes a higher oxide, Fe_3O_4, turns black, and also becomes magnetic. This is mixed in the ratio of four to one of ferric oxide for use in annealing. If a supply of good ferric oxide is available then there is always a source of supply for the black ore. The change is automatic. It is a good conductor of heat, hard and stable.

Other Packing Material.—For black heart castings, anything that is inert, hard, and will leave the castings clean is suitable. Crushed slag, pot scale, old magnetic oxide

volume and pressure of blast, hot molten metal, means a reduction of sulphur in the metal even with cupola melting. The author, when using a 0·150% S pig iron reduced, the S in the castings to 0·12%, a very desirable state when considered in the light of the subsequent anneal. Chemically, the coke should be low in ash, phosphorus, and sulphur, and high in fixed carbon. It should also be of uniform size. A typical analysis of such coke is as follows :—

Fixed Carbon.	Ash.	Sulphur.	Phosphorus.
90—92%	5 to 7	0·38 to 0·7	0·005

Hard Coal and Pulverised Fuel.—This again should be a low ash and high carbon content, both volatile and fixed carbon. Again, the object is hot metal, and it is unwise to use an impure fuel. Impure fuels are usually high in ash, and it is asking too much from impure fuels to give hot metal, or even consistent results.

Other Materials.—These are exactly the same as in use at a grey iron foundry. Sands, binders, core oils, ganister, pattern metal, and so on. These need no special description, therefore. The malleable iron foundry equipment is similar to that of any other iron foundry, excepting the special materials noted in this article. By paying strict attention to these, good results may be expected with very little trouble.

(To be continued.)

NOTES ON IRON & STEEL FOUNDRY PRACTICE.

at a summarised conclusion which can be applied in selecting suitable pig irons according to the type of casting required. Thus, castings of a very light section must have high phosphorus to give the necessary fluidity and length of time during which the metal remains fluid in order to facilitate pouring. Generally, castings of light section require high silicon, while in thick sections low silicon is necessary to secure the requisite softness and hardness respectively. Castings of heavy section should have lower phosphorus, so that the range of solidification is reduced, and the effect of segregation limited.

When castings are required to have strength above the normal only medium silicon and phosphorus should be used, and low total carbon. The maximum percentage

should be present in the mixture consistent with its machinability. This is applicable to the compositions for all castings, in order to close the structure and counteract the influence of sulphur. For castings to resist wear it is important to keep silicon low and the manganese high.

Cylinder castings required to withstand high pressures, both silicon and total carbon should be low and manganese high in order that the structure will be close. For chilling castings much depends upon the thickness of section, particularly the silicon content. This should be as low as the section will allow ; low total carbon ; the sulphur can be high for thick work, but not more than 0·13% ; while both phosphorus and manganese should be about a medium percentage. Castings to withstand high temperatures should have a composition in which both silicon and total carbon are kept fairly low, phosphorus from low to medium, and high manganese. More than ordinary care is required with castings of this composition, and annealing is frequently of value.

(To be continued.)

Notes on the Centrifugal Casting Process

By J. E. Hurst.

Many Mechanical and Metallurgical Difficulties Required to be Overcome Before the Process Became a Successful Commercial Proposition.

WHILST the origin of the centrifugal casting process can be traced back nearly 120 years, it is only during the last few years that it has acquired an established position amongst metallurgical processes. In fact the successful re-introduction of this process is one of the most important advances in metallurgical methods of the past few years.

In its broad outline this process, consisting of the introduction of molten metal into rapidly rotating moulds, as a method of producing cylindrical castings, is now familiar to most engineers and metallurgists. The internal periphery of the mould is made to the required shape and dimensions of the external form of the casting. No core is used or required, and suitable end-closing walls are usually plain annular rings, to prevent the displacement


Fig. 1.—Group of Cylinder Liners and Sleeve-valve Liners, produced by the Centrifugal Casting Process.

of the liquid metal in the direction of the axis of rotation. The molten metal is introduced into this rotating mould in a suitable manner, and the centrifugal forces resulting from the rotation of the liquid metal tend to distribute it towards the inner periphery of the mould. When the metal solidifies a hollow casting results, the external shape corresponding to that of the internal shape of the mould, and the internal bore of the casting, as defined by the end walls of the mould, is either truly cylindrical or of a more or less paraboloidal form, according to whether the axis of rotation is horizontal, vertical, or inclined.

These broad principles were embodied in the early British patent of Anthony Eckhardt (No. 3,197 of 1809). Since this date numerous patents for detailed improvements and applications have been granted to various inventors, amongst whom figure some of those famous in metallurgical history—e.g., Bessemer, Whitley, Fox, Maxim, and others. During recent years this process has been revived under various new patents, and is being operated in this and other countries on an extensive commercial scale for the production of cylindrical castings. From the point of view of mere quantity production the most important application of the process is in the production of cast-iron straight pipe. The Lavaud system, named after its inventor, M. Sensaud de Lavaud, is in full commercial operation in the principal manufacturing countries of the world. At the Stanton Ironworks in this country thousands of tons of pipe per annum are produced by this process. A somewhat more recent development in the production of cast-iron pipe by this process is the Moore Sand Spun process, which is in full operation in the United States.

In spite of the fact that the outputs are considerably less, the application of the centrifugal process to the production of the highest grade of castings for cylinder liners, piston ring drums, and other similar purposes is by no means of less importance. The development of this aspect of the process is essentially British, and is carried out in this country under the process covered by the Stokes and the Hurst-Ball patents. The illustration, Fig. 1, shows a typical group of special cylinder and sleeve castings in cast iron produced by this process.

As applied to the production of castings in steel, the centrifugal process is operating on the production of cast-steel wheels, small cylindrical castings, and various forms of hollow ingots. In non-ferrous materials the process finds commercial application in the production of brass tubes for propeller-shaft liners, paper-mill roll sleeves, gear-wheel blanks, pump liners, and white metal bearings. The application of this process to the production of pipes in concrete and the lining of cast-iron and steel pipes with concrete and hydrocarbon linings should be mentioned also. It is intended to describe briefly some of the principles underlying the successful operation of the process, with special reference to the system with which the writer is connected. The difficulties which have had to be overcome in the successful adaptation of this process have been stupendous, and both of a mechanical and metallurgical nature. These notes will be confined largely to the metallurgical aspect of the process.

AXIS OF ROTATION.

The essential features of the centrifugal casting process are the spinning and solidification of the metal in the mould, and the introduction of the molten metal into the mould. In the principal processes in commercial operation the moulds are rotated about an horizontal axis or an axis slightly inclined to the horizontal. Rotation about the vertical axis is also used to a limited extent. From experience the general rule would appear to be that spinning about the vertical axis should be adopted for those cylindrical castings in which the radial thickness is exceptionally great in comparison to the length—e.g., wheels, locomotive piston

heads, short length, thick section annular bushes. In all other cases where the radial thickness is small in comparison to the length, rotation about the horizontal axis, or approximately the horizontal axis, is to be preferred. Rotation about an inclined axis, steeply inclined to the horizontal, has been practised for the production of small piston-ring drums for automobile engine purposes. There does not appear to be any particular advantage in this method of spinning. A lower speed of rotation can be used than in the case of the vertical axis, but this must be set off against the increased complexity of the design.

THE METHOD OF POURING.

The method of introducing the molten metal into the rotating mould is the principal feature which differentiates the various systems of centrifugal casting. In the majority
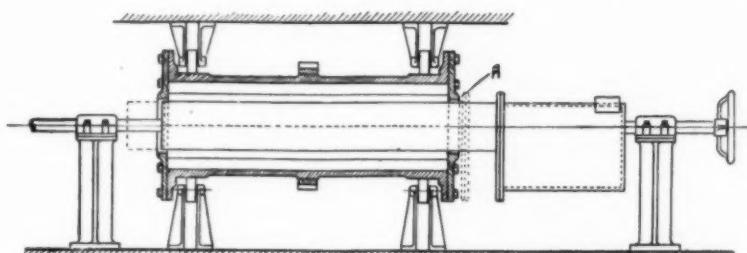

Fig. 2.—Diagrammatic Arrangement of the Tilting Trough of Millspaugh.

of systems where it is required to produce castings to close limits of dimensional accuracy, and particularly where metal moulds are used, the method of pouring is the most vital and important feature of the process. Where the limits of accuracy are not so great, and where the castings are of short lengths and comparatively bulky, the method of pouring is not nearly of such vital importance.

In pouring a quantity of liquid into a rotating mould, no matter in what fashion, providing the liquid remains liquid, it will eventually become evenly distributed over the surface of the mould, and assume a condition of equilibrium in which, in the case of spinning about the horizontal axis, the inside surface is truly cylindrical. In the case of liquid metal, which is only liquid for a short period of time before it becomes finally solid, and, moreover, during this period is increasing in viscosity at a rapid rate, the time available for the liquid metal to take up a condition of equilibrium over the whole surface of the mould is extremely limited. For the production of castings uniform in bore and thickness, it is necessary that the molten metal shall have sufficient time to distribute itself evenly, or some method of pouring adopted in which this time element is rendered of less importance in determining the even distribution of the metal.

The earliest method of introducing molten metal into moulds rotating about the horizontal axis was the use of some form of a bent funnel. Such a bent funnel suitably mounted projecting into the die parallel to the axis of rotation would allow the molten metal poured from an ordinary ladle to be directed on to the surface of the mould in a continuous stream. The even distribution of the whole liquid metal over the surface of the mould is acquired by the movement of the liquid metal over the surface of the mould in a direction parallel to the axis of rotation. This movement is brought about purely by the forces originating from the rotation of the liquid metal itself. The magnitude of these forces and consequently the rapidity with which these movements are brought about and completed depends upon the rapidity with which the molten metal acquires

rotational velocity in the first place. For this reason this method of pouring is only satisfactory on comparatively short lengths of castings of a bulky nature where a considerable quantity of metal is required.

With the object of reducing the length of time required for the molten metal to distribute itself evenly over the whole length of the mould, the obvious method of pouring at several points or over the whole length of the mould simultaneously constitutes the next development. In this manner the distribution of the metal over the length of the mould parallel to the axis of rotation is rendered independent to a certain extent of the forces due to the rotation of the liquid metal. The apparatus used to effect such distribution takes a variety of forms. The method of allowing the metal to issue from a series of nozzles in separate streams at equi-spaced distances over the length of the mould was adopted by Whitley. A more modern apparatus, which has been developed along various lines by different inventors, takes the form of a tilting trough of cylindrical cross-section. A portion of the cylinder wall is cut away in such a manner as to form a horizontal weir edge of approximately the length of the casting to be produced. This trough is mounted in such a manner as to enable it to be tilted or partially rotated about its longitudinal axis, and is either large enough in itself to hold sufficient metal for the production of the casting, or is attached to some external reservoir containing molten metal.

A diagrammatic view of an arrangement of such a tilting trough due to Millspaugh is shown in Fig. 2. In the act of pouring the tilting trough is inserted into the rotating mould parallel to the axis of rotation of the mould, and by partially rotating the trough the liquid metal is deposited simultaneously over the whole length of the mould in one stream of width equal to that of the length of the horizontal weir edge.

Various modifications of this apparatus have been made by different inventors with the object of controlling the weight of metal introduced into the mould. In the case of short-length castings, the filling of the mould can be readily judged by the commencement of any metal in
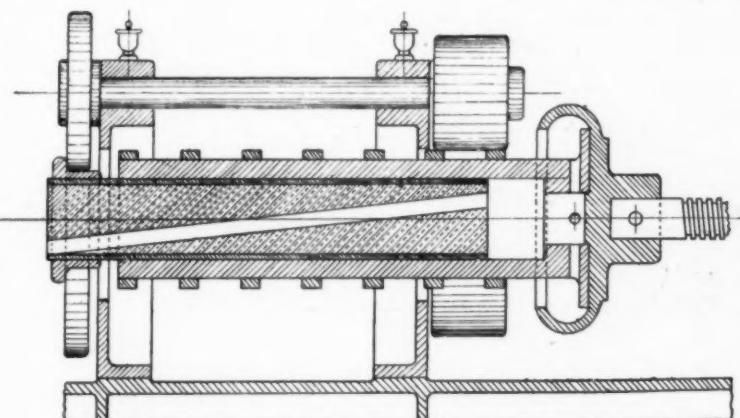
Fig. 3.—Diagrammatic Arrangement of Pourer due to Lane.

excess of that required to fill the mould up to the level of the internal diameter of the end-closing wall A (Fig. 2) to be ejected outside the mould. When this occurs the pouring is stopped, and any excess metal in the trough carried away in a suitable manner.

The exact completion of the length of the casting over and above the length of the pourer is derived from the longitudinal movement of the metal on the mould surface. In long length castings of 12 ft. or more the determination of the exact time of the completion of pouring to secure

such long castings exact in weight and dimensions, and also to ensure the elimination of defects due to gases trapped between the film of metal and the mould in this type of pourer, particularly when applied to castings of long length, is not an easy matter. These difficulties have been appreciated from the earliest days, and Whitley, in 1884, designed a special form of his multiple nozzle pourer to overcome these defects. Instead of allowing the multiple streams to be continuously directed on to the same point of the mould surface, thus necessitating the intervening distance being covered by the longitudinal travel of the metal due to the centrifugal force, he arranged that a reciprocating motion be applied to the pourer, the amplitude of which was arranged that the stream of metal was applied at different points lying on a helix on the mould surface, the lead of which was equal to the distance between the nozzles. By this means the whole length of the mould surface was covered with a series of interlacing spirals independently of the longitudinal movement of the stream due to the centrifugal force, and ample opportunity was allowed for the entrapped gases to escape both in front and along the edges of the advancing metal streams. This method, which was applied to castings 9 ft. long, does not secure the object of regulating the thickness and weight of the casting, any more readily than the ordinary tilting trough.

A further method has been adopted by various inventors in which the metal is poured on to the mould surface in a stream of narrow width. This stream is distributed evenly over the mould surface by moving the suitable pouring spout longitudinally across the surface of the mould, or by moving the mould longitudinally over the pouring spout. Lane, in 1891, adopted this method of moving the mould over the spout during the pouring operation, and at the same time applied a rotary motion to the metal stream. Sir Hiram Maxim, in 1895, arranged a machine for the continuous production of tubes, in which the tube casting was continuously withdrawn from the pouring spout. Briede, in Germany in 1912, designed a machine embodying this relative longitudinal movement

Fig. 4.—Diagrammatic Arrangement of Briede's Pourer and Machine.

Fig. 5.—Stanton Layaud Cast Iron Pipe Spinning Machine.

of the pourer spout and mould. Diagrams illustrating the Lane and Briede arrangements are shown in Figs. 3 and 4.

The Lavaud system embodies this idea of relative longitudinal movement of pouring spout and mould with a number of important improvements. This is illustrated diagrammatically in Fig. 5.

In the Hurst-Ball system relative longitudinal movement of the metal stream with the mould is obtained in a

modified form of tilting trough. In the form as adopted in practice, the tilting trough consists of a cylindrical trough having a portion of the cylindrical wall cut away in such a manner as to leave a weir edge which is a portion of an helix. With a weir edge of this type the height of any point on the edge progressively increases from one end of the trough to the other. If a stream of metal is flowing down this trough, then on partial rotation of this trough the metal commences to flow over the lowest portion of the edge and successively over the higher portions of the

edge as they are brought into the lowest position by virtue of the partial rotation. The effect of this is that the molten metal stream commences to pour at one end of the rotating mould, traversing longitudinally the surface, completing the pouring at the opposite end of the mould.

The principal advantage of these methods of pouring is the control which can be exercised over the rate of pouring. Under the conditions of a constant volume of molten metal flowing down the trough at a uniform rate, the amount of metal deposited on the surface of the rotating mould depends upon the rate of longitudinal travel of the metal stream along the mould. If this travel is at a uniform rate, then the metal must be deposited uniformly over the mould surface. In this manner the even thickness of the casting is independent of its longitudinal travel under the influence of centrifugal pressure, and since the quantity of metal delivered is at a constant rate the quantity deposited is more readily controlled within the time limit available.

THE ROTATING MOULD.

Metal moulds are extensively adopted in the various centrifugal casting processes in commercial operation. In the case of the Lavaud system these are generally water cooled and the castings are treated to an annealing process whereby any chill remaining on the surface of the castings is definitely removed. In the production of grey iron castings for piston rings and cylinder liners, metal moulds are used under carefully controlled temperature conditions in such a manner that the resulting castings are grey and machinable and definitely free from chill. Experience has proved that these conditions can be obtained, using metal moulds either water cooled or atmospherically cooled, and that these conditions concern the temperature of the inside surface of the mould and the temperature gradient

across its radial thickness. With ordinary foundry irons, containing as low as 1·4% silicon, castings can be produced systematically free from chill.

The use of sand moulds in the centrifugal process has been resorted to since the earliest days of the art. In the centrifugal casting of non-ferrous alloys they are still used extensively. In these cases the lower first cost of the mould is often of vital importance owing to the comparatively limited number of castings being required of exactly the same size. The sand mould has been adopted in the Moore Sand-spun process, already referred to in the manufacture of cast-iron pipes. The time of solidification of the molten metal in sand moulds is considerably prolonged. This is taken advantage of in the Sand-spun process, in which the molten metal is allowed to distribute itself evenly under the longitudinal forces due to its rotation. Where metal moulds are used, it is probable that every known alloy of reasonable cost having any pretensions to heat resistance has been experimented upon as a mould material. In the Lavaud process the water-cooled moulds are of alloy steel. Cast-iron moulds are employed exclusively in the processes dealing with the production of piston-ring drums and cylinder liners. All metal moulds eventually fail and become useless. The failure is due to several causes, the principal of which are the scoring and general wear and tear as a result of the continued extraction of the castings and the gradual cracking of the surface, and surface disintegration due to the continual temperature changes to which the moulds are subjected.

The design of the mould has an important bearing on its life. Plain cylindrical moulds of uniform section give the greatest life. Failure through surface disintegration and cracking invariably commences at any change in section. Small diameter moulds generally have a shorter life than the large diameter moulds, and in the large diameter moulds cast iron steadily becomes more satisfactory as the material for mould construction. The failure of the mould from general wear and tear is obviously proportional to the number of castings made. Whilst the failure through surface cracking is partially affected by the thermal conditions and the weight of material or the quantity of heat handled by the mould, it also bears some relation to the number of castings made. For these reasons the life of the die does not at any rate decrease with the increase in diameter. In fact, all the evidence tends to show that the life might be expected to increase with increasing diameter. In the larger diameter moulds the greater clearance between the mould and casting resulting from the greater amount of diametral shrinkage has an important bearing on the mould life.

(To be continued.)

Melting Metals Electrically

By A SPECIAL CORRESPONDENT.

Cleaner Melting, Uniformity of Heat Imparted, and Accuracy of Control are Important Factors Favourable to the Use of Electricity.

DURING recent years considerable developments have been made in the use of electricity for melting ferrous and non-ferrous metals. Until recently it has been commonly regarded as an extravagant melting medium, primarily due to the fact that it has been the custom to compare the cost of generating a given number of B.th.u. of electrical energy with the cost of providing an equivalent number of heat units by other means, without making proper allowance for the much higher efficiency that is obtained from electricity in a properly designed furnace. In fuel-fired furnaces the thermal efficiency is so low, and the transfer of heat by electricity so high, comparatively, that much less fuel may be necessary to generate the amount of electricity for melting than is required when using the fuel direct. But even though the cost of electricity, measured in B.th.u., may be greater, other factors have a considerable influence in determining the ideal melting medium. Cleaner melting, uniformity of heat imparted, and accuracy of control are important factors favourable to the use of electricity. The ease of operation and the absence of combustion gases are also qualities of great value. Reductions in the cost of generating electricity are in a measure responsible for the developments in the use of this melting medium, but the increasing need for more complicated castings and the recent progress in the use of alloy steels are other factors that have given considerable impetus to the use of electricity for this purpose.

STEEL MELTING.

The use of the electric furnace for melting steel has many advantages, the most important of which is undoubtedly the complete control it gives over the chemical and physical conditions required to make good quality metal. The physical characteristics are sufficiently improved to give a high ratio of elastic limit to ultimate strength and to exhibit great endurance under vibration or fatigue tests. The steel melted can be kept under a deoxidising slag long enough to give occluded gases an opportunity to escape, and as the metal is thoroughly deoxidised, the steel produced is dense and homogeneous. A charge may be held in a modern electric furnace until the analysis has been checked without damaging the steel, and modifications can be made if the quality is not consistent with specification ; further, the control is such that the metal can be cast at the temperature best suited for a particular composition of steel.

The value of alloy steels for many classes of work is now apparent, and the melting unit must produce the highest quality of the special composition and maintain it with regularity. The characteristics imparted by the alloy inclusions should not be curtailed, and losses from oxidation must be reduced to a minimum. The exactness in temperature control and cleanliness of operation favour the use of the electric furnace for this purpose.

Electric furnaces for melting steel may be acid or basic lined, similar to open-hearth furnaces, and, providing they are designed on modern lines, the temperature is always under the control of the operator. The use of alternating current makes this comparatively easy, as it involves transformers, and the voltage between electrodes can be varied by means of selector switches which control the temperature. The ability to maintain a high temperature keeps the slag in a fluid condition, whether it is basic or acid. In the basic-lined furnace both sulphur and phosphorus can be materially reduced, which permits the use of a comparatively low-grade of scrap to be charged. In the acid furnace, on the other hand, the sulphur and phosphorus are not reduced, which results in an increase in percentage due to a reduction between output and charge by the formation of slag. A better grade of metal must necessarily be used in the charge of the acid furnace to obtain the quality of steel desired. In this respect the electric furnace does not differ from the open-hearth furnace.

The earlier type of electric furnace developed for melting steel was the arc furnace, and the best known are the single-phase two-electrode " Heroult "; the two-phase type, " Electrometals," and the three-phase type, " Greaves Etchells." In the two latter types the hearths were constructed to carry an electrode at the bottom, the current passing through the metal. These bottom electrodes complicated the operation and have now been superseded by overhead electrodes. The heat in these furnaces is developed by an arc between the electrodes and between an electrode and the metal to be melted, and it must be conveyed by radiation or conduction. When the arc is made between two electrodes the heat from it is radiated to the charge of metal, but when the arc is made between a carbon electrode and the metal the heat is caused by conduction. The current used may be continuous or alternating, although the advantages attached to the latter have made its use almost universal. Continuous current involves costly generators to supply current at low voltages, and troubles frequently arise from electrolytic action. The alternating current, on the other hand, enables the electrical energy to be transmitted at a high voltage and subsequently reduced by a transformer to a low voltage, suitable for the furnace. The three-phase current is more generally used in modern furnace practice.

The use of induction furnaces is meeting with considerable success in the production of the highest quality steels. These furnaces are so called because the heat is obtained by the current induced in the metal charge. Alternating current is necessary, and the furnace becomes a transformer, the primary circuit being supplied with a current at a high voltage, and the bath of metal forming the secondary circuit in which the current is induced. The heat is generated by the passage of the secondary current through the charge. There is no loss of heat in this furnace, since the heat is generated in the metal. The operating costs are low, yet it gives great rapidity in melting, and causes the alloys to mix violently, which results in the production of steel having greater homogeneity than is obtained with the same degree of regularity from other processes. These furnaces are of simple construction, and some are designed with the pouring spout in the axis of tilting, in order that the steel can be poured direct into moulds.

IN THE IRON FOUNDRY.

The electric furnace has not made great headway in the iron foundry, nor is it likely that it will do so for a considerable time. The efficiency of the cupola is comparatively high, and for speed and economy in melting it is not likely to be superseded for general work. It is probable that with developments in cupola design even better results may yet be obtained from this valuable melting appliance, but for many of the intricate castings used in modern internal combustion engine work, the electric furnace should eventually be found profitable in this country. In America its value for certain classes of work has been recognised for a considerable time. For melting iron the duplex process is almost always, if not always, the most economical process, the iron being removed from the cupola to the electric furnace for superheating. The improvement in quality of metal produced, coupled with increased machinability, has proved very satisfactory, and developments in this direction may soon be expected to cope with the increasing demand for high-duty cast iron. The arc type of furnace is generally used, but an induction furnace is giving results with cast iron of a very promising nature, and it is likely that further developments with this type of furnace will show that it can be usefully employed for mixing and superheating high-quality cast iron and also the special quality of cast iron required in the making of malleable castings.

Electric furnaces offer certain advantages in the melting of brass in addition to those previously referred to. Unlike fuel-fired furnaces, there are no combustion gases likely to influence the charge. Instead of adopting means to limit the effect of these gases on the metal, the electric furnace solves the problem by eliminating the trouble at the source. The arc furnace similar to that used in steel melting has not been as widely used in brass melting, due to the intensity of heat radiated from the arc, which causes overheating of the metal, and results in serious loss from volatilisation. In consequence of this difficulty, arc furnaces for brass have been developed with a rocking or rotary motion, in order to distribute the heat in the charge. The rocking type arc furnace has met with considerable success in America, but induction furnaces, either of the vertical or horizontal type, in which the heat is produced internally, have several advantages over arc furnaces. An outstanding one of considerable importance is the thorough mixing to which the metal is subjected, due to electric forces, which results in a perfectly homogeneous alloys. This type of furnace has found wide application in brass foundries, particularly when the brass mixture is of regular composition. The necessity of leaving fluid metal in the furnace to facilitate the melting of the next charge is a disadvantage when various mixtures are required intermittently. This type of furnace is being developed for non-ferrous alloys of higher melting temperature than brass in order to render its use economical for nickel brass alloys.

A RECENT DEVELOPMENT

The coreless type of induction furnace is a more recent development of the application of high-frequency currents to the melting of metals. Unlike the ring type, it possesses the advantage of being capable of continuous or intermittent melting, allowing for the changing of composition of each melt, if necessary. This furnace is being developed for melting special alloys of high temperature, and has not yet met with the same ready and successful application in non-ferrous work as with special alloy steels, but further developments will no doubt result in its wider use for special non-ferrous alloys. The larger electric furnaces have, in relation to their output, a smaller surface than the small sizes, in consequence the losses caused by cooling down are relatively low, and, owing to the greater efficiency, the larger furnaces are more economical. But small furnaces are, as a rule, preferable in foundries, in order to maintain that degree of flexibility characteristic of fuel-fired furnaces without the disadvantages associated with the latter.

It is very probable that very soon the continued development in the use of electricity as a melting medium, and improvements in furnace design, will result in electric furnaces becoming a necessity rather than a refinement, when quality and economy of production are the primary factors.

LEAD POISONING SAFEGUARDS.

In modern works it is now recognised that the health and welfare of the operators is of vital importance, not only from a humane aspect but with a view to regular and economical production. This is particularly true of those industries in which the workers are subjected to the harmful influence of lead and its oxides. Elaborate arrangements are taken by the Chloride Electric Storage Battery Co., Ltd., to reduce poisoning from this cause to a negligible figure.

Adjoining the shops where the workers handle lead or lead oxides, are dressing rooms fitted with hot and cold shower baths, and many special appliances, from special soaps to special jets for mouth washing. Every man has a private tooth brush, and is required to clean his teeth at the works.

As a further precaution the works have a resident doctor, who devotes the whole of his time to supervising safeguards and in the study of lead poisoning. Periodical blood examinations of the workers are made and, by this means, it is claimed that any increase in the amount of lead absorption in the blood can be detected long before there is any sign of the complaint in the worker.

This method enables measures being taken to remedy any defective process, and practically ensures freedom of the workers from lead poisoning.

Some Structural Characteristics of High Chromium Irons and Steels

Part II.

By J. H. G. MONYPENNY, F.INST.P.,

Messrs. Brown Bayley's Steel Works, Ltd., Sheffield.

IN the first part of this article, attention was directed to the microstructural changes produced on quenching various high chromium irons from a series of gradually increasing temperatures, and to the fact that the peculiar effects thus obtained were due to the action of chromium on the A.3 and A.4 changes in iron. As a result of this action, the γ form of iron was eliminated from carbonless alloys containing more than about 15% chromium. Attempts to embody the observed structural changes in diagram form resulted in that reproduced in Fig. 16, in which the broken lines represent part of the iron-carbon diagram and the thick, continuous lines the corresponding changes in steels containing 15% chromium. The latter diagram is admittedly incomplete, and only approximate as regards the position of some of the lines drawn, but it agrees with the observed structural changes. What may be expected, however, if the chromium content be raised still higher ?

probable, however, that this critical carbon content is rather low, because appreciable amounts of austenite are formed in an alloy containing 20·4% chromium and 0·10% carbon when quenched from temperatures in the neighbourhood of 1,200° C. A B C again represents the beginning of the Ac. 1 change, and above this temperature, with less carbon than is indicated by B D¹ G, the steels consist of mixtures of ferrite and austenite, together with any undissolved carbide. The reversal of slope of the line at D¹ indicates that the amount of austenite, in any particular steel, reaches a maximum at this temperature, and thereafter decreases as the temperature rises still higher. To the right of B D¹ G the steels consist of austenite, together with free carbide at still greater carbon contents.

It is admitted that Fig. 17 is largely speculative, as the structural conditions existing in such alloys are still

Fig. 16.—Effect of 15% chromium on the iron-carbon diagram.

CARBON CONTENT.
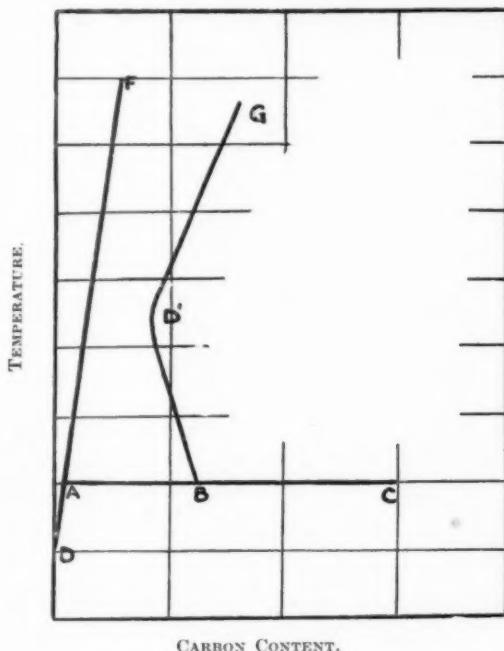
Fig. 17.—Possible form of diagram for 20/25% chromium.

The position of line D F in Fig. 16, as compared with the corresponding line for the iron-carbon diagram, means that the solubility of carbon in δ-iron (or what amounts to the same thing, in α-iron) is increased considerably by the presence of chromium. Presumably, the addition of more chromium than 15%—*e.g.*, 20%—would lower further the position of this line. The extra chromium would also probably tend to raise the temperatures at which the Ac. 1 and Ac. 3 changes occurred, so that a simplified diagram for 20—25% chromium steels may be drawn roughly, as in Fig. 17. Such a diagram means that austenite would not form until a certain minimum amount of carbon was present. If less were present, it would dissolve directly in the α- (or δ-) iron, though probably prolonged soaking at the necessary temperatures would be required to obtain equilibrium and even diffusion of the carbon. It seems

rather obscure. A factor which increases the difficulties of determining an equilibrium diagram for these steels is the very slow rate at which the particles of carbide react with the ferrite surrounding them and constituting the bulk of the material. For example, little apparent structural alteration was produced by reheating a steel containing 0·42% carbon and 25% chromium, for at least an hour, to any temperature up to 1,300° C., and quenching therefrom (see curve D, Fig. 3*) ; in every condition it appeared to consist of ferrite and carbide, and, moreover, the distribution of the latter did not seem to change to any noticeable extent. At the same time, the fact that such high chromium material—if containing enough carbon— will harden on quenching is indicated by curve F in Fig. 3.*

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* See Part 1 in last month's issue.

What is the practical importance of these complex changes ? The engineer may perhaps concede that the elucidation of the effect of chromium on the ranges of existence of γ– and δ–iron forms an interesting theoretical study for the metallurgist, but he may reasonably inquire as to what practical value can be placed upon such speculations. Admittedly, such diagrams as Figs. 16 and 17 are at present rather speculative, but some of their consequences are of very great practical importance. As an example, a stainless iron containing 17% or 18% chromium and 0·1% carbon, may be considered. A bar of this, which has been rolled or forged and afterwards tempered at about 700° C., in the same way that one would treat a lower chromium stainless iron, will consist of grains of ferrite through which are dotted particles of carbide. These grains of ferrite, owing to their high content of chromium, no longer possess a change point ; they do not give rise to γ iron when heated, and hence are not refineable by heat-treatment ; if by any chance they are given a coarse structure, they can only be refined again by mechanical work. But, it may be asked, how does the carbide act ? Should not austenite be formed from this if Figs. 16 and 17 are correct ? Austenite is indeed formed, but only to a limited extent ; only part of the ferrite is absorbed, and, moreover, the action is extremely sluggish. The reason for this will be obvious when it is remembered that the ferrite itself remains in the α condition in which the carbide is still, at about 900° C., only very slightly soluble. A slow action takes place at the interface between each carbide particle and the ferrite surrounding it ; as a result of this, a small nucleus of austenite is gradually formed, and this slowly dissolves the ferrite in its immediate vicinity. One might almost regard the action as being due to the carbide dissolving the surrounding ferrite.
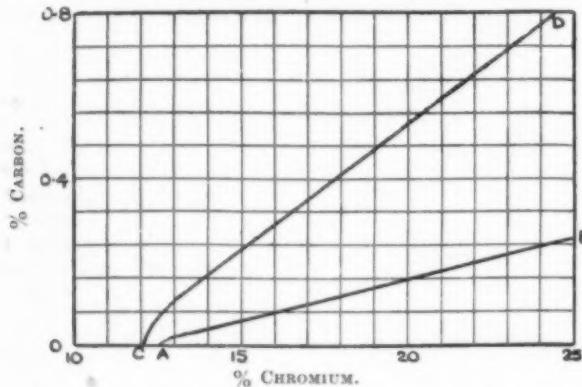

Fig. 18.—Hardening capacity in relation to carbon and chromium contents. (E. C. Bain.)

Evidence of the slow nature of this reaction may be obtained by comparing curve E in Fig. 2* with curve E in Fig. 3*. These refer to two materials which, though differing in carbon, have the same chromium content. Hence, the Ac. 1 change should occur in the two at the same temperature. The quenching tests on the higher carbon steel show that this temperature lies in the neighbourhood of 850° C. On the other hand, the lower carbon material does not harden appreciably until the quenching temperature exceeds about 1,000° C. The striking difference between the two hardening temperatures would appear to be due partly to the sluggishness of the solution of the carbide in the surrounding ferrite of the low carbon iron.

One can also find here an explanation for the very marked difference between the hardening curves of the stainless irons containing 16·0 and 17·2% chromium ; curves D and E Fig. 2.* It is known that the carbide in all high-chromium steels consists largely of chromium carbide.

*See Part I in last month's issue.

Recent determinations of its composition by B. Kalling,† indicate that it contains 5·3—5·4% carbon and about 63% chromium ; the carbide in an iron containing 0·10% carbon will thus account for about 1·2% of chromium. It may be presumed, therefore, that the ferrite of the 16% chromium iron contains rather less than 15% chromium, and hence probably possesses a γ range of its own. On the other hand, with about 16% chromium as the probable content of the ferrite in the higher chromium iron, this constituent will possess no α–γ change, and hence this material has to depend on the sluggish action of the carbide, as suggested above, for any production of austenite to take place when it is heated. Considerations of this nature also account in part for the difference in behaviour between the low- and high-carbon steels described in the last paragraph. The ferrite of the high-carbon steel contains
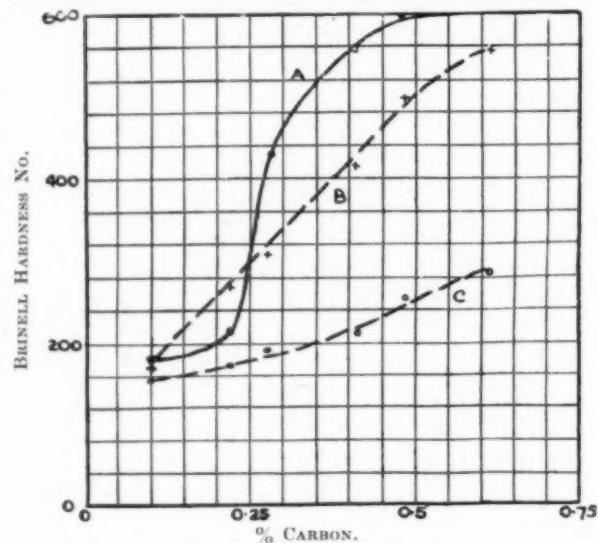
Fig. 19.—Effect of carbon content on the hardness of 17% chromium steels.

Curve A.—Bars 2 in. sq. air-cooled from 1,100° C.
„   B.— „   1¼ in. diam. oil quenched from 950° C.
„   C.—Oil-quenched bars after tempering at 700° C.

less chromium than that of the other, owing to the greater amount locked up in the carbide of the former steel, and possesses, on this account, a γ range of its own.

It follows from the structural changes of high-chromium steels, which have been discussed, that the latter may be divided into three groups :—

(1) Those which do not harden appreciably and are not refineable by heat-treatment.

(2) Those which harden and may be refined by heat-treatment in a similar manner to the stainless steels and irons of lower chromium content.

(3) An intermediate group which hardens to a limited extent and is partially susceptible to heat-treatment processes.

From the point of view of resistance to corrosion, group (1) is the most desirable, because that part of the chromium which exists in the steel as chromium carbide does not exert any beneficial influence on the resistance of the metal to corrosion. On this count, therefore, carbon should be kept as low as possible. Unfortunately, however; the mechanical properties of these low-carbon materials are deficient in certain important respects. With a carbon content of the order of 0·1%, those which contain up to about 14% chromium harden appreciably and are susceptible to heat-treatment. Above 16%, they have a negligible hardening capacity, and are not refineable by heat-treat-

ment. Alloys with compositions between these two values harden to some slight extent. Dealing with those containing over 16%, the lack of hardening power in itself is not particularly serious ; it may be an advantage for some hngineering purposes. The impossibility of refining by eaeat-treatment operations is of much greater moment as the ductility of these irons deteriorates markedly when their grain size becomes coarse. Not only does this imply that a close control must be kept on forging and rolling temperatures, but also that the ductility of the material when in the form of bars or forgings of large size, is not likely to be nearly so good as in small-sized articles, owing to the impossibility of producing a fine grain size in the article of large sectional area. The bad effects of coarse grain size are also evident, sometimes painfully so, when the material is welded. On either side of the weld there is produced a band possessing a structure similar to that in Fig. 8,* and as it is impossible to refine this structure by any form of heat-treatment, welding operations on these high-chromium irons are seldom very satisfactory.

A further disadvantage, and one that may probably be traced back to their structure, is the very pronounced grain growth to which they are subject if held at a red heat for long periods. One of the useful properties of high-chromium irons is their resistance to oxidation when heated to relatively high temperatures ; their usefulness as heat-resisting steels is, however, limited in certain directions by the excessive grain growth to which they may be subject and the brittleness which this entails. The readiness with which grain growth occurs in these irons is probably not unconnected with their relative freedom, at these temperatures, from austenite. The latter, if present in any quantity, would obstruct the growth of the ferrite grains.

From an engineering standpoint, however, probably the most serious defect of these high-chromium irons is their notch brittleness. Speaking generally, it may be said that stainless irons containing up to 14% chromium, when properly heat-treated, possess very high Izod impact values, but those with 16% or over have values of the order of 5 ft.-lb., nor can this value be improved by any form of heat-treatment. Between 14% and 16% the impact value varies greatly in different casts, and is not predictable from their analysis. The following values, obtained from bars 1 in. or so in diameter which had been hardened and then tempered at 700° C., are typical :—

C., %	Cr., %	Y.P., %	M.S., %	E., %	R.A., %	Izod Impact, Ft.-lb.
0·07	11·7	30·6	40·4	26·5	65·8	79
0·07	13·3	26·6	38·6	34·0	68·8	110
0·10	14·4	29·6	37·2	33·0	69·8	98
0·09	15·5	18·0	31·8	36·5	65·8	78
0·09	15·5	22·9	32·4	38·0	70·8	10
0·10	17·9	18·0	27·8	40·5	66·8	3
0·10	20·4	18·4	27·9	34·0	49·7	3
0·21	20·1	26·0	37·0	28·0	61·0	4
0·26	23·6	26·4	37·2	28·0	49·7	2

The absence of a reasonable amount of toughness limits the use of the high-chromium irons in many ways.

As regards the higher carbon material, Fig. 18 gives, according to E. C. Bain, the relation between carbon content and hardening capacity of these high-chromium steels. Steels containing less carbon than is indicated by curve A B do not harden ; those with more than corresponds to line C D harden fully. When the composition falls between the two curves, the steel hardens partially. It should be noted that the position of these curves is only approximate, as there is no sharp line of division between the several groups. This is illustrated by the curves in Fig. 19, in which are plotted results obtained from a series of steels containing 17% chromium. Curve A relates to the Brinell hardness values given by bars 2 in. square when cooled freely in the air from a forging heat, about 1,100° C. For curve B, bars 1½ in. diameter were quenched in oil from 950° C. ; curve C gives the further results from the same

quenched bars after they had been tempered at 700° C. The impossibility of fixing a limit dividing hardening and non-hardening steels will be obvious. The writer's experience suggests, however, that the non-hardening group extends to a somewhat higher carbon content than is shown by curve A B (witness, for example, the results for steel D, Fig. 3) ; this curve would certainly need altering in this manner if it were to include all alloys which are not refineable by heat-treatment.

Turning now more particularly to the stainless irons containing 14% or 16% chromium, one may mention two other practical effects resulting from the structural changes depicted in Figs. 4 to 10.* In all high-chromium steels the original dendritic heterogeneity produced in the ingot, and due to selective freezing, persists to a more marked extent than in ordinary carbon steels, owing to the slower rate of diffusion of the carbon in the heated chromium steel. As a result of this, the distribution of the carbon in a cast sample of the ordinary " cutlery quality " stainless steel (about 0·30% carbon and 12% chromium) outlines the original dendritic structure produced on solidification ; and not only so, but this structure persists to a marked extent even through the operations of forging and rolling. In the
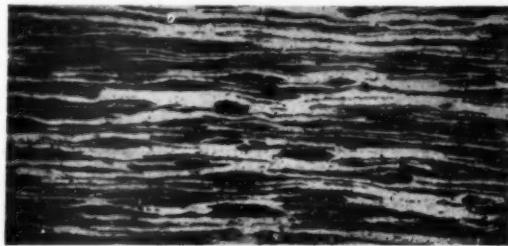
Fig. 20.—Laminated structure of stainless iron plate, ¼ in. thick.

case of the higher chromium irons mentioned above, the structure is even more persistent. An ingot of such material has a structure similar to Fig. 13*–i.e., very large grains of ferrite, with a small amount of sorbite or martensite, depending on rate of cooling after casting. When such ingots are reheated for forging or rolling, the carbon has even less opportunity of becoming evenly distributed throughout the steel than it has with the lower chromium material, because at no temperature is there obtained a structure consisting entirely of austenite. Some free ferrite remains undissolved, and hence there is produced, in rolled or forged products, a sandwich-like structure consisting of bands of ferrite practically free from carbide, alternating with other bands containing variable amounts of carbide, either in or out of solution. A typical appearance found in a rolled plate is shown in Fig. 20. In round or square bars these bands become so many fibres whose size depends on the amount of reduction in cross-sectional area from ingot to bar ; their effect on the properties of the material may or may not be noticeable, depending on circumstances. In flat bars, plates or sheets, however, they will produce a more or less laminated structure, and this may have disconcerting effects when such a structure is a source of weakness.

As a somewhat spectacular rather than an important
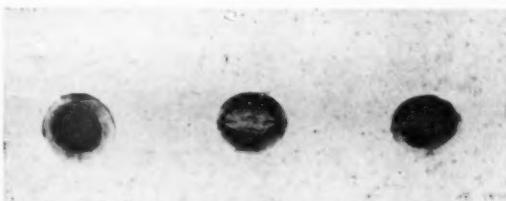
Fig. 21.—Oval fracture of tensile test pieces of stainless iron.

effect, one may instance the oval appearance of the fractures of the test pieces shown in Fig. 21. These were cut from

flat bars of stainless iron of this type. Before testing, the cross-section of each test piece was, of course, circular, and its oval shape after testing appears to be due entirely to the remnants of the ingot structure being rolled out to tiny plates during the operations incidental to producing a flat bar. Similar but less noticeable effects may be produced in stainless irons containing less than 14% chromium, when these are rolled or forged at such high temperatures that they consist structurally of mixtures of austenite and δ–iron. In the case of 12% chromium iron, no noticeable amount of δ–iron appears to be produced until the temperature exceeds about 1,200° C. ; when the chromium content reaches 14%, the corresponding temperature is about 1,100° C.

Fig. 22.—Decarburised skin of 14% chromium iron after heating at 1,150° C. for 20 mins. × 25 diam.

The other effect of the comparatively wide range of existence of δ–iron in these high-chromium irons relates to the production of a decarburised skin on such material when it is heated to high temperatures. The skin produced in this manner on the higher carbon stainless steels, and also up to certain temperatures on the stainless irons, is of a similar type to that found on ordinary carbon steels : there is a gradual decrease in carbon content as one approaches the extreme surface of the steel. If, however, stainless irons are reheated above a certain minimum temperature, depending on their chromium content, decarburisation leads to the production of a sharply defined layer of coarse, practically carbonless, ferrite grains which grow from the surface and possess a columnar structure very similar to that associated with hot cast ingots. Fig. 22 represents the decarburised zone produced on a sample of 14% chromium iron after reheating for 20 mins. at 1,150° C. in a gas-fired furnace. At 1,250° C. the skin was similar, but twice as thick. Prior to these treatments the samples had been machined all over to remove any pre-existing decarburisation. It seems likely that at these temperatures the decarburised skin automatically becomes δ–iron ; as the carbon content of successive layers is reduced by the requisite amount (see Fig. 16) these also change to δ–iron, and, being formed upon the layer of existing crystals of this material, assume the orientation of the latter, causing them to grow in the same way that columnar crystals grow in an ingot from the liquid steel. As δ–iron has a different crystalline form from γ–iron, and can only dissolve a very limited amount of carbon, the inner surface of this decarburised layer is very sharply defined in structure and carbon content, from the normal material inside. This is one of the most striking features of Fig. 22.

The very great depth of the decarburised layer in Fig. 22 should be noted. The production of such a skin, even in so short a time as 20 mins., and under conditions which were not particularly oxidising, is not only important from a practical standpoint, but should also be very carefully borne in mind by those carrying out investigations on the structure, at high temperatures, of steels containing large amounts of chromium. It is probable that more than one investigator has been misled as to the structural changes taking place in these steels, owing to the great depth of the decarburised skin not being realised ; as a consequence, sufficient material has not been removed by grinding or machining from the surfaces of heat-treated samples preparatory to microscopical examination. Hence, the

structural conditions existing in the skin have actually been studied, and have been assumed to represent those present in the undecarburised parts of the samples. Obviously the production of a skin similar to that in Fig. 22 is possible on higher carbon material, providing the surface layer is decarburised to a sufficient extent to bring its composition within the range of existence of δ–iron. The writer has actually found such skins on small microsections of material containing 0.6—0.7% carbon which had been heat-treated at 1,300° C.

CAUSE OF FAILURE OF ZINC COATINGS.

Efforts to ascertain the cause of peeling and flaking of zinc coatings reveal the fact that only a definite knowledge and understanding of the individual conditions will indicate a remedy.

At times a steel base may be extremely hard and brittle, and have a dense, almost glassy, hard surface. The zinc cannot penetrate the pores of the steel and, according to Mr. W. G. Imhoff, in the *Iron Trade Review*, the coating has an extremely low adherence. If this material is formed and stamped, many rejections are caused by cracked and broken seams which warp and open up with the heat of the galvanizing pot. Such material will peel and flake easily if any attempt is made to bend or deform the product.

Occasionally a steel base is of high silicon content, and this steel, when pickled, often has a thin tissue-paper-like skin on it. It is practically impossible to coat this kind of base metal properly, and on very bad steel of this type the coating will not stick at all. In this condition the steel must be washed or scrubbed clean of this film before being galvanized. A close study reveals that each step in the process may be a factor. This requires a knowledge of all the practical conditions, and then tracing the cause to the material used or to the step in the process which is faulty.

The major causes and minor or subordinate causes of peeling and flaking of galvanized coatings are summarised as follows :—

1. *Chemical Composition of Steel Base.*
   (a) High-silicon steel with loose skin on it.
   (b) Very hard, brittle, close-grained steels, which prevent the zinc from entering the pores and alloying with the base metal.
2. *Surface Condition of Steel Base.*
   (a) Steel finished too smooth by rolling process.
   (b) Surface too smooth because too much inhibitor has been used.
3. *Pickling Causes.*
   (a) Poor muriatic acid conditions.
   (b) Dirty pickles, heavy iron salts.
   (c) Unclean, dirty steel surface.
   (d) Iron salts, soot, corrosion, etc., burned on surface by dryer.
   (e) Steel burnt badly in pickle.
   (f) Grease or oil film on surface.
4. *Galvanizing Causes.*
   (a) Purity of zinc.
       (1) Bad zinc ; sluggish metal ; oxides and dirt in it.
       (2) Too high iron content ; poor fluidity ; freezes quickly.
   (b) Temperature of metal bath.
       (1) Too low, cold metal.
       (2) Too high ; burnt brittle coating which flakes.
   (c) Submersion time.
       (1) Too long submersion time due to methods of galvanizing.
       (2) Too short submersion time ; rushed work.
   (d) Withdrawal and draining.
       (1) Coating too heavy, due to rapid drawing and improper draining.
5. *Cooling and Piling.*
   (a) Water quenching—dropped into water too soon after coming out of hot-metal bath.
   (b) Effect of heat ; piling too hot.
       (1) Nested metalware buckets, tubs, etc.
       (2) Boilers standing too close together while very hot.
       (3) Flat pieces and other articles piled too hot.
6. *Weight of Coating.*
   (a) Coating too heavy.
   (b) Submersion time too long ; heavy brittle coating.
7. *Production.*
   (a) Too high—heavy metal deposit.
   (b) Too slow—long submersion time.
   (c) Too large a number of articles in bath at one time.
8. *Bents and Dents.*
9. *Regalvanizing without Stripping.*

Thermal Conductivity of Metals and Alloys

By J. W. DONALDSON, D.Sc.

Recent advances in Engineering have intensified the need for further investigations on this important subject.

THE various investigations carried out on the properties of metals and their alloys have rarely included determinations of the thermal conductivity. This has been due to the difficulties experienced in making accurate determinations. Recent advances, however, in engineering practice, particularly in the construction of internal combustion engines, have shown the necessity for an exact knowledge of this important property, and many investigations have been undertaken. These investigations include determinations on both ferrous and non-ferrous materials.

IRON AND ITS ALLOYS.

The thermal conductivity of pure iron was first determined by Forbes[1] in 1862, and found to be 0·207. Since then experiments on pure and wrought iron by various workers, particularly Simidu, have resulted in other values being determined. These various results have been reviewed by Jakob[2], who concludes that the average value is 0.135. Benedicks, Bäckström, and Sederholm[3], however, found that an iron containing 0.08% carbon and 0.13% manganese gave an average value of 0.187, and they also state Sedström obtained K = 0.18 for very pure electrolytic iron, results which approximate to the 0.207 value obtained by Forbes. Benedicks has calculated the thermal conductivity of pure iron from a formula for the thermal resistivity of steel, and found it to be 0·227, a value which, so far, has not been obtained by experimenting, and suggests that the value given by Jakob of 0·135 is 50% too low, and ought to be replaced by 0·187. Recent work on steels and cast irons would appear to support this view.

Systematic determinations on the thermal and electrical conductivities of carbon steels were first made by Honda and Simidu[4]. Consideration of the results obtained from these experiments, which were conducted on steels containing from 0·1 to 1·5% carbon, and carried out at temperatures varying from 100 to 900° C., show that the average K value obtained is about 0·100 (the conductivity decreasing slightly with increase in carbon content and increase in temperature). On account of these low values, Jakob[2], who made a careful analysis of the results, applied in some cases a correction of + 15%, a correction which Benedicks considers might be higher. Sederholm's values of 0·1316 and 0·1245 for steels containing 0·50 and 0·71% of carbon respectively may be considered as more normal, and are in agreement with thermal resistivity determinations of Campbell and Dowd[5] on a number of steels of widely varying composition. Experiments by the author on a cast steel containing 0·26% carbon gave a K value of 0·134 at 100°, and 0·127 at 400° C. From these results it would appear that the thermal conductivities of plain carbon steels vary from 0·12 to 0·14, according to the carbon content, and decrease slightly with increase in temperature.

RESEARCH ON STEEL ALLOYS.

Researches on the thermal conductivity of alloy steels are those of Matushita[6] on chromium steels, Schultze[2] on manganese steel, and Honda[7] on nickel steels, together with the investigations of Sedström, referred to by Benedicks, Bäckström and Sederholm[3], on iron-nickel, iron-manganese, iron-aluminium, and iron-silicon alloys, and the thermal resistivity experiments of Campbell and Dowd[5], which included manganese, silicon, copper, nickel, and chromium steels.

Matushita experimented with a series of heat-treated chromium steels containing 0·6% carbon, and found the thermal conductivity to decrease from 0·100 with no chromium to 0·043 with 20% chromium. Schulze found the K value of a 10% manganese steel to be 0·03, while Honda showed that nickel added to steel decreased the thermal conductivity of steel up to 30% nickel, when the value obtained was 20% that of steel containing no nickel. The values obtained by those three investigators are low when compared with the values obtained for plain carbon steels, but they demonstrate conclusively the fact that when chromium, manganese, or nickel is added to steel the thermal conductivity is lowered.

Sedström's experiments with iron alloys confirm this, the thermal conductivity value of 0·18 for iron being lowered to 0·15 by 1 atomic % of manganese, and still lower by a similar amount of nickel, while aluminium and silicon have a still greater effect in reducing the heat-conducting property Further confirmation is also found in Campbell and Dowd's work, the relative thermal resistivities of steel increasing as nickel, chromium, or manganese is added.

There are no published records of investigations on the thermal conductivity or thermal resistivity of tungsten or vanadium steels or of tungsten or vanadium-iron alloys.

The earliest conductivity work on cast iron is that of Beglinger, who, according to Jakob[2], examined thirty-one cast irons at 10° C., and found their thermal conductivities to lie between 0·093 and 0·153. This was followed by Callendar's[8] experiments, which gave values for a cast iron containing 2·0% carbon, 3·0% silicon, and 1·0% manganese, as 0·114 at 54° C. and 0·111 at 102° C. A further value for a cast iron containing 3·5% carbon, 1·4% silicon, and 0·5% manganese, is given by Hall[9] as 0·149 at 30° C.

INFLUENCE OF COMPOSITION.

The variable nature of these results led the author[10] to carry out a series of investigations on plain and alloy cast irons. The results obtained indicate that the thermal conductivity of grey cast iron varies from 0·110 to 0·137, and decreases as the temperature increases. The values obtained for thermal conductivity are affected by composition, silicon and nickel lowering the conductivity considerably, while manganese and vanadium have a similar effect, although to a lesser degree. Chromium and tungsten, however, tend to raise the conductivity.

The structure of cast iron has also an appreciable effect on its heat-conducting properties, although not nearly so marked as the composition. Free ferrite appears to be a much better conductor of heat than eutectoid pearlite, this being shown by heat-treating the irons at 550° C., when the pearlite decomposed to form ferrite and graphite, with an increase in the thermal conductivity, which on prolonged heating decreases slightly, due to oxidation of iron in the vicinity of the graphite flakes. This effect of structure has also been noted by Masumoto[11], who found that if graphitisation took place on annealing chill-cast iron the thermal conductivity increased considerably.

Many investigations have been carried out on pure metals and their alloys, but in this review only those are considered which are of industrial importance—namely, copper and aluminium and their alloys, white bearing metals, and nickel alloys.

Values for pure copper have been obtained by Lees, Meissner, Jaeger and Diesselhorst[9], and Schofield[12], and vary from 0·90 to 0·94. Schofield's determinations, which are the most recent and accurate, were made on electrolytic copper, rolled, drawn, and annealed, containing

99·9% copper, and gave the conductivity as 0·901 at 96° C. decreasing to 0·842 at 624·7° C. Arsenical copper, however, has a very much lower thermal conductivity. This has been shown by Williams and Bihlman[13], and by the author[14]. The former investigators determined the conductivity of an alloy containing 99·44% copper, 0·231% arsenic, 0·20% nickel, as 0·52 at 165° C. in its hard-drawn condition, and as 0·50 at 170° C. in its annealed condition ; while the author obtained from industrial arsenical copper to B.E.S.A. specification in its rolled, drawn, and annealed condition, having the composition of 99·53% copper, 0·389% arsenic, conductivity values of 0·512 at 90° C., and 0·527 at 420° C.

INVESTIGATIONS ON ALUMINIUM.

The determination of the thermal conductivity of aluminium has been the work of many investigators, the most recent being that of Griffiths and of Schofield[12]. The former tested aluminium of 99·5% purity and obtained values ranging from 0·50 to 0·52 at 100° C., with a slight tendency to increase in conductivity with increase in temperature up to 250° C. ; and the latter, aluminium of 99·7% purity, when values of 0·53 at 50° C. and 0·542 at 80° C. were obtained. Values obtained by Williams and Bihlman[13] and by the author[14] were slightly lower, approximating to 0·47 at 90° C., this being probably due to the purity of the aluminium, the respective samples containing 0·30 and 0·43% of iron.

INDUSTRIAL ALLOYS OF COPPER.

Investigations on the industrial alloys of copper have been the work of Williams and Bihlman[13], Griffiths and Schofield[15], and the author[14]. The first of these investigators tested four alloys, containing 79 to 87% of copper, 5 to 11% of tin, and varying amounts of lead and zinc. The thermal conductivities over an average temperature range of 145 to 335° C. varied from 0·109 to 0·230, the lower value being due to the presence of 0·30% of phosphorus. The 0·230 value was obtained from an alloy containing equal proportion of tin and zinc. Increase of the tin at the expense of the zinc lowered the conductivity, while lead had also a detrimental effect.

The thermal conductivities of the seven bronzes tested by Griffiths and Schofield varied from 0·09 to 0·20, and in contrast to copper and other pure metals all gave considerable increase in conductivity with increase in temperature. The higher value was obtained from an alloy containing approximately 60% copper, 40% zinc, while a bronze containing 88% copper, 10% tin, 2% zinc had a value of 0·126 at a similar temperature. A comparison of two bronzes of identical composition, except for the presence of a minute amount of phosphorus showed that the latter produces a marked lowering of the thermal conductivity.

SPECIAL EXPERIMENTS.

The author's experiments were carried out on two brasses—a 70 : 30 brass and a complex or high-tensile brass, commonly known as " manganese bronze," two bronzes (the zinc bronze known as " Admiralty gun-metal," and another more generally used in engineering practice, containing higher percentages of zinc and lead), and a copper-tin-phosphorus alloy. The thermal conductivity values obtained ranged from 0·130 to 0·242 at 90° C., and increased with each alloy with increase in temperature. It was shown that alloys of tin and copper have a lower thermal conductivity (0·130) than alloys of zinc and copper (0·240), while in copper alloys containing both tin and zinc the conductivity appears to vary with the relative proportion of those metals present. The presence of phosphorus produces a slight diminution in conductivity.

Aluminium alloys have been the subject of many investigations by various workers on thermal conductivity, Jakob and Czochralski[16] in Germany, Griffiths and Schofield[15] in Britain, and Masumoto[17] in Japan. The alloys examined have included all the commercial alloys of aluminium with copper, zinc, silicon, magnesium, and nickel, and have thermal conductivities ranging from 60 to 80% that of pure aluminium—that is, from 0·30 to 0·45,—and all show increase in thermal conductivity with increase in temperature. According to Griffiths and Schofield the highest conductivity, 0·45 at 80°, is obtained from alloys containing 8% copper and 4·5% copper, and the lowest conductivity, 0·32 at 80° C. from the 13% zinc, 3% copper alloy. The alloy containing 4% copper, 2% nickel, 1·5% magnesium, gave a value of 0·40 at 80° C. Czochralski gives the thermal conductivity of an aluminium-silicon alloy, 11 to 13% silicon, as 0·39 at 30° C., and 0·40 at 70° C.

Experiments on the heating conducting properties of white bearing metals have been the work of Williams and Bihlman[13], who examined the American S.E.A. bearing alloys 10 and 11 over a temperature range of 50 to 100° C., and obtained K values of 0·092 and 0·062. These values agree with those obtained by the author[14] for " Admiralty white metal," 87% tin, 8% antimony, 5% copper of 0·070 at 76° C., and 0·094 at 167° C.

The thermal conductivity of nickel, 0·145 at 100° C., according to Schofield[12], with nickel of 99·2% purity ; and of 0·132 at 100° C., with nickel of 97% purity, according to Honda and Simidu[4] falls off considerably when alloyed with copper. The author[14] found the thermal conductivity of Monel metal 67% nickel, 29% copper, 2·5% iron, 0·5% manganese, to be 0·067 at 88° C., and 0·084 at 415° C., and these results are in general agreement with those of copper alloys containing a large percentage of nickel, Constantan, 60% copper, 40% nickel, having a conductivity of 0·054 at 18° C., and Platinoid, 62% copper, 15% nickel, 22% zinc, a conductivity of 0·059 at the same temperature.

1 J. D. Forbes, " Trans. Roy. Soc. Edin.," 1862 ; vol. 23, p. 133.
2 M. Jakob, " Zeitschrift für Metallkunde," 1924 ; vol. 16, p. 353.
3 C. Benedicks, H. f Åkström, and P. Sederholm, " Jour. Iron and Steel Inst.," 1926 ; vol. 2, p. 127.
4 K. Honda and T. Simidu, " Science Rep. Tohoku, Imp. Univ.," 1917 ; vol. 6, p. 219.
5 E. D. Campbell and W. C. Dowd, " Jour. Iron and Steel Inst.," 1917 ; vol 2, p. 251.
6 T. Matsushita, " Science Rep. Tohoku Imp. Univ.," 1920 ; vol. 9, p. 243.
7 K. Honda, " Science Rep. Tohoku Imp. Univ.," 1918 ; vol. 7, p. 59.
8 H. L. Callendar, " Rep. Brit. Assoc.," 1897.
9 R. Glazebrook, " Dictionary of Applied Physics," vol. 1, p. 443.
10 J. W. Donaldson, " Proc. Inst. of Mech. Engineers," 1928 ; No. 4, p. 953.
11 H. Masumoto, " Science Rep. Tohoku Imp. Univ.," 1927 ; vol. 16, p. 417.
12 F. H. Schofield, " Proc. Royal Soc.," 1925 ; vol. 107, p. 206.
13 H. M. Williams and V. M. Bihlman, " Trans. Amer. Inst. Min. Met. Engr.," 1923 ; vol. 69, p. 1,065.
14 J. W. Donaldson, " Jour. Inst. Metals." 1925 ; vol. 2, p. 43.
15 E. Griffiths and F. H. Schofield, " Jour. Inst. Metals," 1928 ; vol. 1, p. 337.
16 J. Czochralski, " Zeits. für Metallkunde," 1921 ; vol. 13, p. 507.
17 H. Masumoto, " Science Rep. Tohoku Imp. Univ.," 1925 ; vol. 13, p. 229.

RULE FOR GRADE OF GRINDING WHEELS.

It was not generally realised that the foundation of the modern grinding-wheel of the Alundum type was a soft and floury substance, and that by subjecting this substance to the intense heat of the electric furnace it was converted to one of the hardest abrasive materials known. The ease with which the substance could be formed into wheels of widely different contours and degrees of coarseness were very clearly shown by Mr. Sanger in a lecture he gave recently before the Junior Institute of Engineers on " The Age of Speed."

In the discussion which followed the lecturer gave a great deal of information in answer to questions on the proper mounting and use of grinding-wheels, and, for a general rule as to the grade of stone most suitable for any particular job, stated that the wheel which performed the work most quickly and remained just below the glazing point was the one to be chosen. Glazing generally meant too hard a wheel, and excessive wear too soft a one. It must be remembered it was the material used as a bond—i.e., clay, shellac, silicate of soda, vulcanite, etc.—which determined the hardness of the wheel, as the grit was of the same hardness but of different sizes in all wheels. The modern preference for finishing surfaces by honing instead of grinding was referred to, and it was considered that honing would eventually displace grinding for such parts as the interior of cylinders, etc.

Modern Methods of Heat-Treatment

By Samuel Whyte, B.Sc.

Developments in Alloy Steels have Directed Attention to the Necessity for Improved Methods in Heat-Treatment.

THE advent of alloy steels and new tool steels has directed more attention towards improved methods of heat-treatment. The old type of hardener who controlled his temperature by eye has practically disappeared ; the pyrometer has taken his place, and modern methods of heat-treatment are carried out on scientific lines.

The blacksmith's forge is still used, but only to a very slight extent, for the hardening of high-speed steel lathe tools which require hardening on one end only. The modern method of hardening lathe tools is the small high-speed gas furnace with a round chamber about 4 in. long and 6 in. wide. The work should be preheated to about 900° C., otherwise too rapid heating may develop cracks. The hardening chamber is usually run about 1,300° C., and should have an excess of gas so that there is a reducing atmosphere inside the furnace. The old method of hardening off in an air blast gives very good results ; but for many jobs, such as slotting tools, oil-quenching followed by tempering at 590° C. gives more efficiency.

Of recent years the electric furnace has come largely into use for the heat-treatment of high-speed steels. This can be fitted with a regulator which ensures uniformity of furnace temperatures, and, incidentally, gives the maximum hardness efficiency of the steel. The earlier types of electric furnaces for high-speed steels had a very short life, and burned out easily at high temperatures, but the later types have much thicker heating elements, and consequently a much longer life. There is still, however, the problem of oxidation scaling the work, as a reducing atmosphere is very difficult to obtain in these furnaces. Some help may be gained, however, by placing a few lumps of charcoal in the hardening chamber.

THE USE OF SALT BATHS.

The heat-treatment of high-speed steels in salt baths is used fairly extensively in America, and to a lesser extent in this country. The salts are melted in a crucible of the electric-furnace type, or the gas-fired type, but no salts have yet been discovered which are entirely satisfactory. Barium chloride was used in the early days, but was inclined to dissociate at high temperatures and give a soft skin to the work. Later, salts of borax mixtures were used ; but here again slight softening of the outer surface takes place, and, in addition, the salts are often difficult to remove after quenching. The one outstanding advantage in the use of salt baths is the cleanliness of the work after hardening, and to a lesser extent the freedom from distortion, which is due to the uniform heating by this medium.

A more recent method which is very satisfactory for high-speed steel tools that do not require the properties of red-hardness—i.e., running at such speeds that the point of the tool becomes red hot—is the low-temperature method. This is carried out by packing the tools in a carburising box fitted with spent charcoal—i.e., charcoal which has been heated in boxes to a bright red. By this method the work is heated slowly and uniformly to 950° C., and is then soaked at this heat for 3½ to 4 hours, followed by quenching in oil. The tools are clean and perfectly free from scale.

The usual faults met with in the heat-treatment of high-speed steels are brittleness of the cutting edge and poor efficiency. Brittleness of the cutting edge is due to too high a hardening heat, which coarsens the grain of the steel, and, in extreme cases where the temperature has been much too high, oxygen penetrates and forms oxide boundaries to the crystals. Although tools with either of these faults might appear extremely hard under the file test, they will not keep an edge in running. On the other hand, heating at too low a temperature without soaking results in poor cutting efficiency. The iron tungstide and chromium carbides require time to diffuse, and even at a temperature such as 1,280° C. require 4 mins. or more, according to the section.

For testing the hardness of high-speed steels the Rockwell hardness tester, or a machine of the Vickers diamond-point type, gives reliable and consistent results. The Brinell machine with the usual steel ball does not give a good impression for reading, although this machine can also be fitted with a diamond point.

S.H. VARIATIONS IN TREATMENT.

The heat-treatment of tool steels, other than high-speed steels, varies according to the type of steel and to the finish required. The ordinary gas-muffle furnace is still in more general use than any other, and with skill it is hard to beat. There are now, however, two or three electric furnaces on the market which record the change point in the steel, so that it is easier for a non-skilled hardener to obtain excellent results. One furnace of American design records this change point by the heat absorption of the steel while passing through the critical range, while another of British design uses the loss in magnetism. In either case the steel should be allowed to pass completely through the change point before quenching. Quenching in this way from the lowest possible temperature minimises distortion. It also gives the metal the finest possible grain, so that maximum hardness is obtained without brittleness.

For alloy tool steels, such as non-shrinking oil-hardening 1·5% manganese and 1% carbon or ball-bearing steels of varying chromium contents, these electric furnaces which record the change or " recalescence " point are very useful, and the correct hardening temperature is obtained with great facility. There is, however, usually a difficulty in keeping a reducing atmosphere in these furnaces, and scale or oxide may be formed on the surface of the tool. For some jobs this would be very serious, and in these cases salt or cyanide baths are resorted to. The former, however, which are usually mixtures of sulphates and chlorides, tend to produce a slight softening on the surface of the tools, though there are a number of mixtures on the market which are very satisfactory in this respect. With the latter, which usually consist of sodium cyanide with or without dilution by chlorides or borax, there is no chance of a soft skin being formed, as carbon is actually added to the steel, and the surface should have its maximum hardness. In both cases the work is protected during heating, and the tools are clean and bright after hardening.

PACK HARDENING.

Pack-hardening in spent charcoal is not satisfactory for tool steels other than those containing high percentages of chromium or tungsten. The usual carbon tool steel, with or without small proportions of manganese or chromium, should not be soaked too long at the hardening heat. With pack-hardening a liberal margin must be allowed, so as to ensure that the box is heated throughout and the work is at a uniform temperature. This tends to over-soaking, and gives a coarse grain, with consequent brittleness.

Some plain carbon tool steels show a "divorced" structure before hardening. This is produced by prolonged annealing below the recalescence or change point, which treatment is usually carried out when the steel is required in its very softest condition for an accurate drawing operation. The normal pearlitic structure is changed, and the lamellæ of ferrite and cementite become broken up, and the cementite collects into isolated areas dispersed in the ferrite matrix.

If tool steel in this condition is hardened in the ordinary way—i.e., quenched without soaking at the hardening temperature—it is found that some of the cementite areas still remain unabsorbed, and this means that the maximum hardness cannot be obtained. To restore the proper structure, the tools can be given a preliminary normalising at a high temperature (900° C.) and then hardened in the usual way, as this preliminary treatment reabsorbs the free cementite. Sometimes a slight soaking at the hardening temperature (about 760° C.) is sufficient to give good results, but the high temperature normalising for steel in this condition gives the best hardness efficiency.

CASE-HARDENING STEELS.

For heat-treating casehardening steels the usual method is to pack in boxes, the time and temperature of soaking depending on the steel and the depth of case required. Alloy casehardening steels such as 3% nickel, or 3% nickel 1·5% chromium, require longer soaking for the same depth of case as compared with plain case-hardening steel, but the comparatively slow rate of change means that they are practically "foolproof" in hardening. That is, if the hardening temperature is too high or the work is kept too long at the hardening temperature, which are the usual causes of a brittle core in a plain carbon steel, the work is very little the worse. The boxes for packing are usually made of boiler-plate, cast iron, or castings of a high nickel-chrome alloy. Boxes of boiler-plate treated on the surface by a protective coating are also on the market, but the high nickel-chrome alloy castings give by far the longest life, and are more economical.

With regard to casehardening compounds there are a number on the market, some being of the energised charcoal type, while others are of the animal charcoal type. Care should be taken to choose one which is not too energetic at an average temperature, such as 900° C., otherwise the carbon content on the outer surface will be too high and the case be brittle. This is conveniently determined by the micro-examination of a test-piece after carburising. Where excess of carbon is present the cementite will be seen as isolated areas, or as continuous bands around the crystals of pearlite.

ROTARY FURNACES.

For small work a rotary furnace is very satisfactory, and is much more rapid than the pack-hardening method. With the rotary furnace only a comparatively small amount of compound is required, as the carburising gases come into contact with the work while under pressure. In some cases no compound is used, only gases with or without catalysts, such as ammonia gas.

Rotary furnaces are now being used to a large extent in America for much bigger articles, such as camshafts, etc., and for cases where the depth is 1·0 mm. or over. The work is comparatively clean ; but if there is a deep case, it is usually necessary to give refining heats for core and case, as the carburising period would be sufficient to enlarge the grain size of both. To preserve a clean finish under these circumstances the work should be reheated in a salt or cyanide bath. The cyanide bath is also very useful for articles such as screws, etc., which require only a very thin but hard case. Many object to the use of cyanide on account of the poisonous fumes, but if one uses a bath of medium strength—say, 45% cyanide (remainder chlorides, etc.), instead of pure cyanide, and at the same time cover the surface of the bath with graphite—there are practically no fumes. At the same time the usual exhaust fan and hood are often used as an extra precaution.

PROTECTIVE COATINGS.

In casehardening work it is often necessary to leave some places soft, and a good method of local hardening is very desirable. The old method of leaving extra metal where softness is required, and machining it off after carburising, is very satisfactory, except that it necessitates re-setting of the work for the machining operation, with consequent loss of time. Copper plating is also fairly satisfactory. Those parts required to be left soft are covered with copper in an ordinary electric-plating bath. The work is then carburised in the usual way, except that the carburising gases do not pass through the copper, and in consequence one can obtain any desired results. Sometimes, however, the copper coating is porous, and this, of course, is fatal, as the carburising gases pass through easily.

There are on the market protective paints which act as anti-carburisers and protect the parts so coated while in the carburising pots. During quenching this point falls off or it can be removed before the reheating operations. This is a very satisfactory method for obtaining soft areas where desired.

NITRIDING PROCESS.

The new process of hardening special steels with ammonia gas must also be mentioned. The steels usually contain silicon, aluminium, or chromium, or combinations of these, and a nitride case is formed on the surface. It is claimed that with this process there is no distortion of the work, the finish is clean and the surface extremely hard. As the work is carried out at a temperature between 450° C. and 500° C., no quenching is required afterwards. This removes the principal causes of distortion, and if the steel or rough machine parts are normalised or heat-treated first in the usual way to give the desired physical properties to the core, any movement during the nitrogen process is reduced to a minimum. From the writer's experience, however, there is usually a slight expansion. Although this process is very slow—i.e., 90 hours are required to produce a depth of case of 0·8 mm.,—the hardness is from 900 to 1,100 Brinell. Unfortunately this cannot be tempered down in any way, and where strength and toughness are required with hardness it is found that the nitrogen case is too brittle and may crumble in service. The class of work to be hardened by this method must therefore be chosen with discretion.

AN ECONOMICAL ELECTRICAL POWER STATION.

With a fuel consumption of 1·33 lb. of coal per unit generated, and a thermal efficiency of 21·35%, the Padiham power station of the Lancashire Electric Power Co. takes premier place in the Electricity Commissioners' report for the year ending March 31, 1929. This achievement is the more remarkable as Padiham comes in the "50-100 million units generated" group of power stations, there being two groups with higher outputs, namely, "100-200 million" and "over 200 million" units. Thus Padiham ranks as the most efficient power station in Great Britain, irrespective of size and output. It may be added that the British Thomson-Houston Co., Ltd., of Rugby, supplied all the electrical equipment for this station, in addition to the turbo-alternators.

A NEW METAL TO RESIST HIGH TEMPERATURES.

A new metal, known as "Konel," has been placed on the American market, which is claimed to be highly efficient in the moving parts of internal-combustion engines and other extremely hot places. World patent rights have been granted for it. This metal was originally evolved as a substitute for platinum in the manufacture of wireless valve filaments. It has been found to be more difficult to forge than steel, and also to be very tough at high temperatures. The cost of platinum in America is about £36 per ounce, while the new metal can be made for about £1 a pound. Wireless valves fitted with the new metal filaments can be worked at 175° F. colder than valves with platinum filaments, but with the same emission.

Principles and Uses of Wire Rope
Part III.

By Walter A. Scoble, D.Sc., M.I.Mech.E.
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Treatment of steel, process of drawing into wire, and subsequent tests to which it is submitted.

THE first stage in the manufacture of wire rope is the formation of strand by twisting a number of wires together, after which a number of the strands are laid up into a rope. Certain exceptions will be noted later, but one is mentioned here because it may otherwise be overlooked. Suspension bridges, for example, have cables which are not always constructed as above. Sometimes the wires are laid parallel to each other, bound with wire to hold them together, and are covered with a weather-resisting material to afford protection to the wire. Such cables form part of a structure, and do not move appreciably. They are not ropes in the ordinary meaning of the term, but they afford an example of the advantages of the high tensile strength which results from the wire drawing, and of the flexibility of a bunch of parallel wires compared with that of a single member of equal sectional area. The individual wires are sometimes a quarter of an inch or more in diameter, so the rods from which the wires are drawn must be much larger than usual to permit sufficient drawing to give the required high tensile strength.

When the wires are twisted together as a whole, the combination usually is referred to as a strand, and wire is often used in this form when strength is desired, but great flexibility is not essential. Well-known examples are strand for fencing, signalling, stays, and for tension members in certain structures, such as aircraft.

The principle of a machine which lays wires into strands is the same as that of the machine which forms strands into rope. Stranding machines run at high speed and are enclosed for safety, but on this account it is not possible to learn much about their construction from an outside view. Fig. 1 is an illustration of an armouring machine, which is included by the courtesy of Messrs. Johnson and Phillips, of Charlton. Steel wires are being twisted round

Fig. 1.   An Armouring Machine.

an electrical cable, to give mechanical strength, in exactly the same fashion that wires are laid into a rope strand, so this is a large stranding machine, and the photograph allows the method of working to be followed without difficulty. This machine also embodies two different methods of stranding. Each wire is wound on a drum or bobbin, which is carried on a pin. A brake, usually a simple rope affair, offers a resistance to the rotation of the bobbin on its pin, and adjusts the tension under which the wire is laid in the strand. These brakes can be seen at the left of the figure. The bobbins are carried on " fliers," which rotate and twist the wires round the core, whilst the strand is pulled through a die by the rotation of a drum, not shown, on the right, on which the completed strand is given sufficient turns for driving purposes. It will be seen that the bobbins on the first disc work on pins fixed to the flier, with the result that each corresponding wire is twisted once about its own axis for each turn about the core. The axis of the bobbin rotates with the flier, and the six bobbins are inclined differently in the illustration. The axes of the other reels are seen to keep horizontal to avoid torsioning the wires, a gimbal arrangement being provided for this purpose. The die appears on the extreme right. The driving drum is geared to the flier, and their relative speed can be adjusted to give the required pitch to the wires in the strand. The strand makes only a few turns in one layer over the driving drum, from which it is coiled on a storage drum.

The difficulties in dealing adequately with rope construction are considerable, mainly because the wire combinations are so numerous. It is evident that ropes must be built up in different ways to suit the various uses to which they are put, but there is no sufficient excuse for the enormous number of constructions which are manufactured. It seems probable that individual
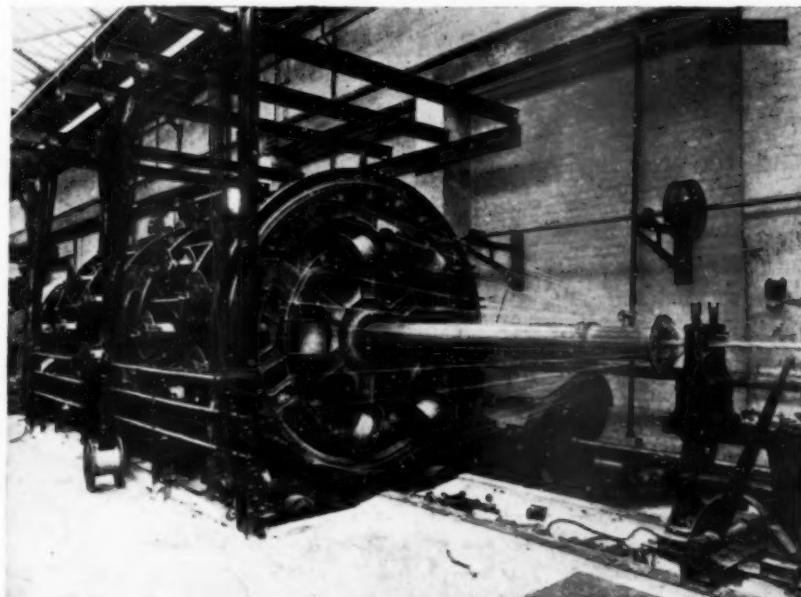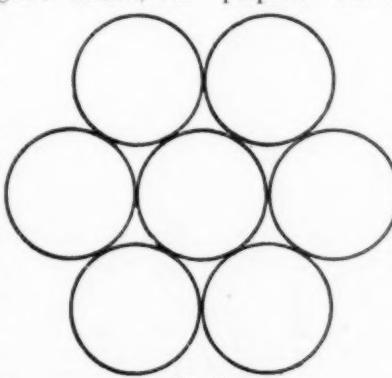

Fig. 2.

manufacturers introduced new rope constructions with the object of meeting a special demand or of producing a speciality, but it is surprising that so many forms of rope are still in demand. It is realised to-day that concentration on fewer models cheapens production and further lowers costs by reducing the stocks which must be kept.

The wire-rope manufacturers appear to desire reform in the direction of fewer rope constructions, but they hesitate to do much because they are still asked for special features. Until recently little experimental work had been done on wire ropes by methods which represent service conditions, and there is little doubt but that this is the reason why many constructions have not been proved unsuitable, or at least unnecessary. Engineers can help the manufacturers and themselves by demanding normal ropes unless it has been proved that such cannot be used for their purpose. It will be seen later that a general guiding principle in the selection of a rope is that it should be kept as simple in construction as the conditions of service will allow.

The most favoured constructions build up the strands in the manner now described. Six wires are twisted into helices around another similar wire, which acts as a core, to form a seven-wire strand. The section of the strand is usually illustrated as in Fig. 2. The matter is not quite so simple as the diagram indicates, consequently it will be analysed to bring out the reasons for modifications which are met with but which are not generally understood.

Referring to Fig. 2, if the wire diameter be denoted by d, then the diameter of the circle which passes through the centres of the outer wires is $2\,d$, and the circumference of this circle is $6\cdot28\,d$. The latter figure leads some people

Fig. 3.

as an ellipse. If a line be drawn from the centre of the core wire to the centre of the outer wire, the diameter of the outer circle at right angles to this line should be increased to convert the circle into the ellipse. Thus, it follows that when the six wires are twisted round an equal core wire, they cannot all bear upon it unless they crush into each other along their lines of contact. To avoid this crushing, a core wire is frequently used of somewhat larger diameter than that of the six wires.

There is another reason for the adoption of a larger core wire. After a strand has been under tension it is found that the outer wires bed slightly into the core wire, which will be understood when it is noted that otherwise there is merely line contact between the wires. The core wire should be large enough to relieve the pressure between the outer wires after this bedding-in has taken place.

Another modification, the desirability of which is not so certain, is the use of a core wire of lower tensile strength than that of the main wires. This practice is based on a consideration of the stretch of the strand under tension. When this takes place the core wire must elongate the same amount as the whole strand, whereas the apparent lengthening of the outer wires is partly due to a straightening of their helical form. The true stretch of the core wire is greater than that of the outer wires, consequently it is more highly stressed until its elastic limit is exceeded. When a strand of seven wires of equal tensile strength is tested in tension, the core wire should break first. It has been explained that drawing wire increases its tensile strength at the expense of a reduction of its elongation. Low tensile wire has a greater elongation at fracture than the main wires of a rope, and the former is used for the core wire to allow it to
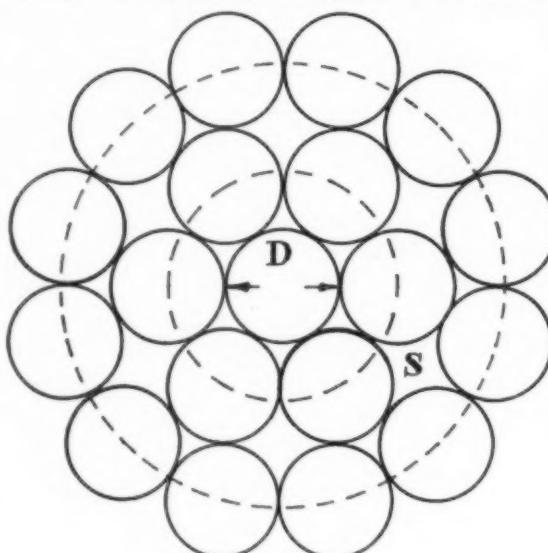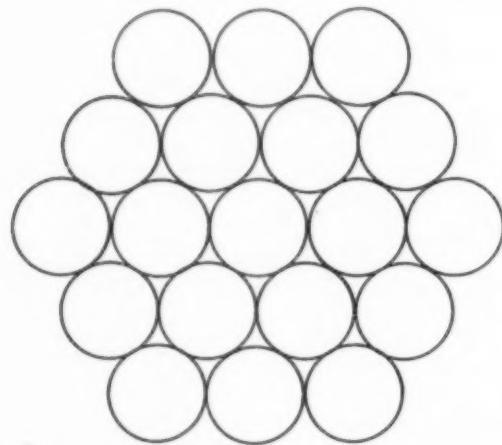
Fig. 4.
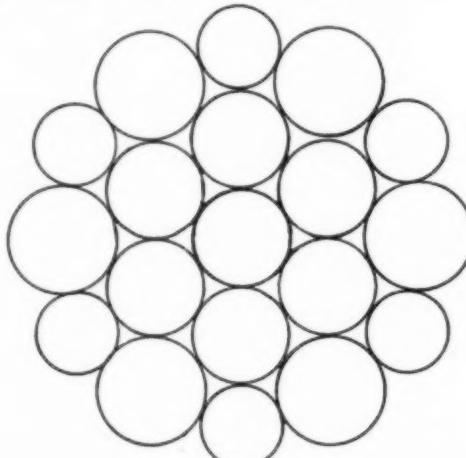
Fig. 5.

to conclude that there is room for six wires, with some over to meet a further need. This is not correct: six equal circles just fit round another of the same diameter, and the distance between the centres of adjacent outer wires is measured along a chord of the circle through the centres, not along the arc. Fig. 2 is correct for seven wires parallel to each other, whereas actually the outer wires are twisted round the core wire and the section of each should appear

elongate without fracture until the outer wires are fully stressed. Under tension the outer wires squeeze on the core wire and move relatively to it, so there is an indenting and cutting action. A low tensile core wire is relatively soft, and does not damage the outer wires, but it also should be sufficiently ductile and malleable not to fracture under the severe treatment noted above.

It has been shown that if a rope be considered to be

equivalent to a number of parallel wires which can move freely on each other, then such a rope will have greater flexibility as the number of wires of which it is composed is increased. The rope becomes more flexible, both in the

lower tensile strength than that of the main wires, and, like a soft core wire, they are not considered to contribute to the strength of the rope.

The ill-defined space in 19-wire strand are sometimes
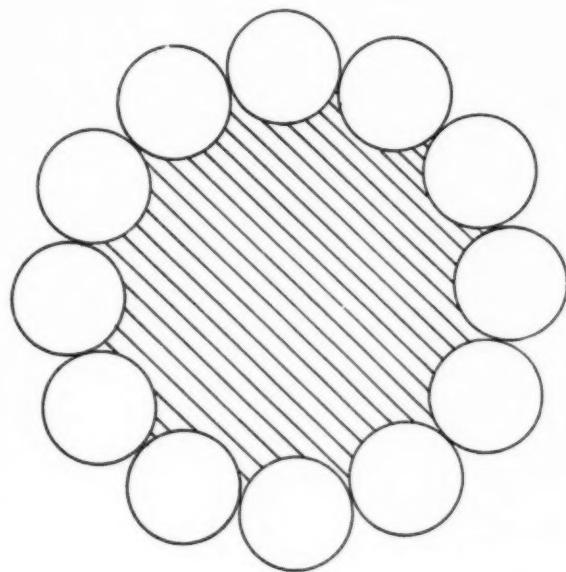
Fig. 6.
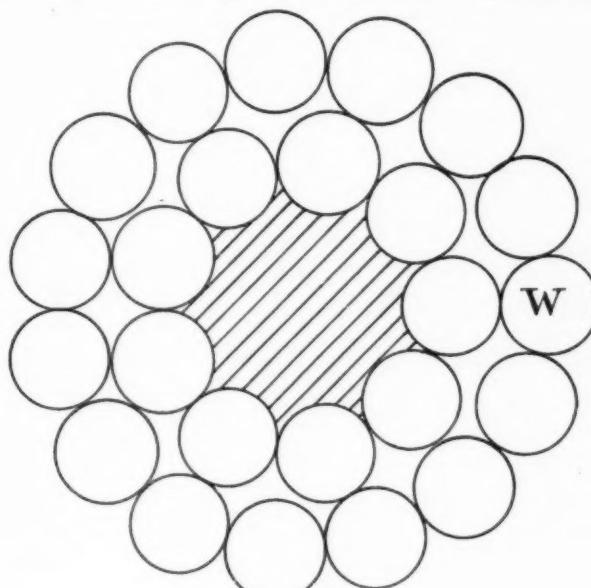
Fig. 7.

sense that it is more readily bent and also the wires take less bending stress when the rope is bent with any given radius.

The next stage of development from the seven-wire strand, to give greater flexibility, is the 19-wire strand. It must be realised that when the flexibilities of these strands are compared, equal strengths are assumed, and the total wire sections of the strands are nearly equal. Here, again, it is sometimes assumed that the centres of another layer of wires, laid over the six, lay on a circle of diameter $4\,d$. The circumference of this circle is $12\cdot57\,d$, and it appears that 12 wires of the same diameter as the six can be used for the second layer. Reference to Fig. 3 makes it clear that not only is it incorrect to think of the distance between adjacent wires as being measured along the arc, but also that the wires bed together and the diameter of the circle is found to be only $3\cdot864\,d$. This being so, it is surprising that the 12 wires fit in so well. The sections of these wires should be ellipses, and a larger core wire is required to increase the diameter of the circle on which the centres of the 12 wires lie, and so to afford room for the wires as inclined in the actual strand.

The building up of a strand is continued further for more flexible ropes, the next stage being the addition of another layer of 18 wires to make a 37-wire strand, and then still another layer of 24 to make a total of 61 wires. The latter is considered to have extreme flexibility, and is used only in exceptional circumstances.

Fig. 3 shows the 19-wire strand as it is usually made, and in a form which is probably satisfactory for small ropes. The wires in the outer layer are not completely constrained, and it is conceivable that one of them might take up its position in the valley between two wires of the first layer, and push the adjacent wires to the top of those in the first layer. This is shown in Fig. 4. The incomplete constraint is associated with the spaces marked S in Fig. 3, and such spaces are met with in other strands which are built up on different lines.

One method which is sometimes adopted to eliminate the uncertainty of the construction is the use of " Filler " wires, which fit in spaces such as S, and the figure shows that the 19-wire strand needs six such wires. Filler wires have a

eliminated by the arrangement shown in Fig. 5. Alternate outer wires lie in the valleys of the inner layer, whereas the other outer wires ride on the inner wires. The outside of the strand is made smooth or regular by using larger wires for the valleys and smaller for the crests. This type of 19-wire strand is named the " Warrington."

Several other strand forms are simple modifications of the standard strands of 7, 19, and 37 wires, in which similar wires are laid on in successive layers. One of the most obvious examples is the 12 wires on a fibre core, Fig. 6, which is similar to the 19-wire strand except that the inner seven wires are replaced by a fibre core which forms a bed for the 12 wires. It is clear that this core can be made of any required diameter to allow a different number of wires to be used, so that it is possible to have, for instance, eight wires laid over a fibre core.

Flexibilities are demanded which are intermediate between those dealt with so far, and the need is met by having strands with intermediate numbers of wires. It was noted that when equal wires are used in successive layers, the numbers of wires in adjacent layers differ by six—thus, 6, 12, 18, 24. This fact is combined with the use of a fibre core to the strand, whose diameter can be adjusted to suit any number of wires in the inner layer, to build up a strand of 24 wires. Fig. 7 shows how this is effected, by using nine wires on fibre with an outer layer of 15 similar wires, but it seems certain that the alternate wires W of the outer must wedge in and bear on the wires of the inner layer.

(To be continued.)

BRITAIN'S SPEED RECORDS.

The year 1929 will be remembered as being Britain's " fastest year " ; the first time this country holds the world's speed records for land, sea, and air. Numerous motoring records of speed and endurance have also been achieved in all parts of the world by British drivers. The most important records are the epoch-making achievements of Sir Henry Segrave, who drove his " Golden Arrow " car at 231 miles an hour on Daytona beach, and broke the motor-boat record of over 90 miles an hour in " Miss England," and the achievement of Flight-Lieut. Waghorn, who won the Schneider Trophy for Britain at a speed of 328 miles an hour.

Reviews of Current Literature

TRANSACTIONS OF AMERICAN SOCIETY ON STEEL TREATING.

THE oft-remarked characteristic of our American cousins : their willingness to try anything new as opposed to our own somewhat conservative attitude towards startling inventions has again shown itself with the Krupp nitrogen hardening process. That nitriding has created tremendous interest in the United States there is no doubt, and this is further evinced by the papers presented at a recent symposium on this subject at the annual convention of the American Society of Steel Treating in Cleveland, on September 13. The papers, with the oral and written discussion they aroused, are now available in book form. They cover various phases of the nitrogen hardening process, and include a short paper by the inventor, Dr. Adolph Fry, of Messrs. Krupps of Essen.

The first paper deals with the hard white layer formed in the bore of gun tubes during service due, according to the theory advanced by the author, to nitrification of the steel by contact with hot gases at high pressures. The similarity of this layer in many respects to the case of a nitrided steel is shown, and theories advanced for the mode of formation and probable constitution in both instances. In the next paper S. Epstein gives the results of further research work on the iron-nitrogen system done at the Bureau of Standards.

An enormous amount of careful work (including X-ray analyses of nitrided specimens) leads the author to suggest modifications to the existing iron-nitrogen diagrams due to Sawyer and Fry. Whilst it would be foolish to suppose anything like finality has been reached in our conception of this complex system, most of Epstein's conclusions are based on sound premises, and his tentative diagram seems reasonable and will form a valuable basis for further studies.

The paper, from the joint pen of V. O. Homerberg and J. P. Walsted, is of special interest, as Dr. Homerberg, in his capacity of consulting metallurgist to the sponsors of the process in America—the Ludlum Steel Co.—is known to have devoted much time to both the academic and practical aspects of nitriding. It gives much useful data on the effects of variation in nitriding procedure as regards heat-treatment of steel, varying rate of flow of ammonia gas, and varying temperature. In the discussion on this paper much interesting information is given on the application of nitriding for valve seats and discs, and factors influencing its resistance to corrosion.

Dr. Adolph Fry, in a short resumé of the various problems connected with the process, touches on some very salient points, many of which still await elucidation. He stresses particularly the disadvantages resulting from employment of high temperatures for nitriding (550°—650° C.), and the necessity of eliminating all machining stresses and stresses caused by heat-treatment if freedom from distortion during nitriding is aimed at.

The results of investigations carried out at the University of Minnesota under the leadership of Dr. O. E. Harder, are given in a paper which discusses the effect of nitriding on various steels other than the chrome-aluminium-molybdenum steels usually employed. Further experimental work on the effect of nitriding temperature, gas dissociation, and condition of the steel is recorded.

Comparisons between the nitriding process and the ordinary case-hardening process are made in a contribution by Robert Sergeson, and demonstrate the superiority in hardness of the outer layers of nitrided specimens, whilst at greater depths the carburised and quenched specimens are harder. Interesting curves are also given, showing how nitrided specimens retain their high hardness, even at temperatures as high as 600° C.

Methods of determining brittleness in nitrided cases are discussed, and suggestions made to eliminate any tendency to brittleness by the use of a duplex nitriding temperature. This method, which is supported and practised by several of the writers, does not meet with the approval of the inventor, nor is it practised in Germany and France.

McQuaid and Ketcham, in a somewhat generalised paper, contribute their experience of the process and indicate the necessity for further research on many important features. A paper of great practical interest on the use of nitrided steel in high-pressure, high-temperature steam service is that by V. T. Malcolm, who is metallurgical engineer with the Chapman Valve Co.

The comparison of service results given by nitrided seats and discs with those obtained with such materials as stainless steel and monel-metal is strongly in favour of the former. The paper would, however, have had added value if tests had been included of the special nickel-chrome and nickel-copper-tin alloys of high initial hardness which find favour for similar duties in this country.

The general effect of the symposium is to indicate an appreciable divergence of opinion as to the best methods of nitriding between various workers.

None of the papers give much indication as to the limitations of nitrided parts for such work as heavy concentrated loads and for services involving shock.

It is fairly safe to predict that much further research work is needed before the procedure for nitrogen hardening is stabilised, and many of the suggestions contained in these papers will be abandoned. The book will prove of great assistance to workers in this field, and should most certainly be in the hands of everyone interested in the nitrogen hardening process. F. W. R.

NITRIDING SYMPOSIUM OF THE AMERICAN SOCIETY FOR STEEL TREATING. 222 pages. Price (cloth bound), $3.50. Published by the Society, 7016, Euclid Avenue, Cleveland, Ohio.

PIPE AND TUBE BENDING AND JOINTING.

From the earliest times lead and copper were used in the making of pipes, and the plumber and coppersmith were the only craftsmen responsible for shaping and bending them. Other metals have been applied, as they have been developed, with the application of machinery, and the number of trades in which pipes play an important part has been considerably increased. In a general sense there are two methods by which metal pipes may be bent to a desired shape. The first by working up sheet metal to form saddle and back pieces, the halves being joined up with a seam along the sides to form a pipe of the required shape. The second method is by forcing the pipe or tube from the straight to the curved shape necessary. By this method the metal at the throat is compressed while that at the heel is extended and reduced in thickness.

In dealing with so many metals, Mr. Marks has found it difficult to refrain from the repetition of a treatment ; some repetition has been unavoidable, but it has been reduced to a minimum. While the major part of the work is confined to various metals in which primary consideration has been given to bending and various forms of joints, space has been found for a chapter on electric conduit and ebonite tubing, which cannot fail to be of practical value to those responsible for fixing electric cables. The subject matter and illustrations have been well devised, and must have been based on a wide experience. The author, in his preface, states that the book is an endeavour to place matter of practical value before its readers, so that they may obtain instruction and guidance in practices associated with pipe work and also to form a handy work of reference on pipe and tube work generally. There is no doubt that the assimilation of the methods described, together with facilities for applying them, will increase the skill of anyone responsible for one or other of the kinds of pipe-work, because it is essentially a practical book.

By Stanley P. Marks, M.S.I.A. Published by Sir Isaac Pitman and Sons, Ltd., Parker Street, Kingsway, W.C. 2. Price, 2s. 0d.

Refractory Materials

Examination of Refractories in the Laboratory.

Part II.—*Continued.*

By Colin Presswood, B.A., F.G.S.

Expansion Tests.

THESE are designed so as to measure, in the laboratory, the volume changes occurring when the materials are heated. Such tests are most important, so far as concerns the user, in relation to burnt bricks and shapes, though they are by no means to be neglected in the case of raw powders, compositions, pastes, etc., or of mixtures containing some considerable proportion of raw, or unburnt, material.

SEGER CONES

BEFORE HEATING **& AFTER**
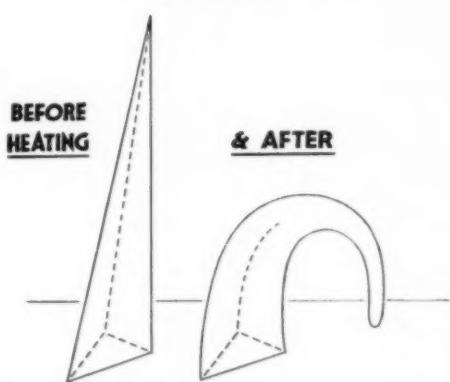
Dealing in the first place with burnt refractory shapes : It is well known that when raw refractory materials are burnt they generally undergo a permanent volume change. It is the manufacturer's duty to see that such volume changes are as nearly completed as is possible under industrial conditions, and the economic factors imposed thereby. The volume changes correspond to chemical and physical reactions which are often slow, and the burning has necessarily to be stopped before the reactions are completed. The reactions are "arrested" by the cooling following burning in the kiln. In furnaces the heating is prolonged for weeks—sometimes for years, during which time the changes may be completed, and, in fact, others may start. Whilst in use in the furnace, bricks may therefore suffer a *permanent volume change*—either an expansion or a contraction. On cooling, the bricks do not recover their original size.

Now such changes may take place even though the temperature in the furnace is lower than that of the kiln in which the bricks have been fired—the important factor being time. By wise manipulation of his materials and selection of his burning conditions in relation to those of the furnace in which his bricks are to be used, the manufacturer can reduce the "after-contraction" or "after-expansion" of his bricks to reasonably low figures.

Such changes are obviously important to the user, and the "after-expansion" test is designed to give an indication of their extent. It is a matter of no small difficulty to standardise such a test—a specification should really be made in relation to every distinct set of furnace conditions. In general, however, the Gas Engineers' Specification is used, though with the development of refractories science other industries will doubtless evolve their standard tests.

Part of a brick to be tested is heated to 1,410° C. and held at that temperature for four hours in the laboratory furnace.

The change in dimensions is expressed as linear expansion or contraction per cent., and less frequently as volume change per cent. Measurement is a matter for care, especially if the perpendicular distance between two parallel faces of the test-piece is observed. A line may be drawn on one of the smooth faces of the test-piece.

In this test the nature of the change depends on the type of material, fireclay, magnesite, and bauxite tending to shrink, and silica to expand. Qualification is necessary, and will be dealt with under those parts of this series of articles which deal with specific types of refractory materials.

In the case of raw or unburnt materials and mixtures of these with burnt material or "grog," permanent volume changes are important. Examples are jointing cements, compositions for patching and ramming linings and moulding sands. To test these a series of briquettes should be made with the amount of water likely to be added in use and the volume change on heating to various temperatures should be observed. In this case the drying shrinkage should also be observed. Such a test is vitally important in the case of those compositions intended for use in ramming monolithic walls to displace brickwork. In these the total volume change (including drying and burning) should be very low, as the size of the "one-piece" wall may be considerable. The changes are usually, though not always, expressed as percentage of the original dimensions.

In almost all such materials plasticity is a characteristic, and depends largely on the raw materials present. Generally, the larger the amount of "grog," or previously burnt material, the lower will be the shrinkage, and the grog content is to be as high as possible consistent with maintaining plasticity. Ground fireclay for jointing firebricks

FIG. 2.

EXPANSION — UNDER LOAD OF

FIRECLAY BRICK ------

SILICA BRICK ————

MAGNESITE BRICK —·—·—·—

(DIAGRAMATIC ONLY.)
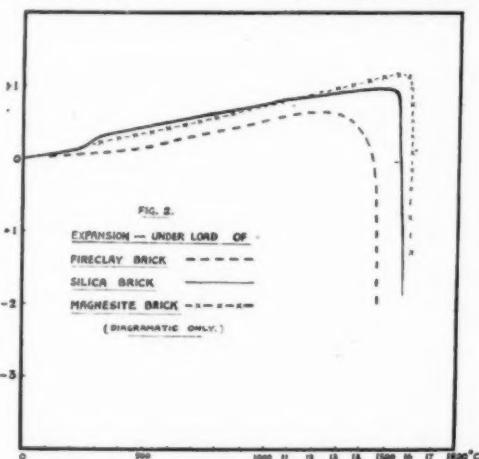
should always be mixed with crushed brick, the fineness depending, of course, on the nature of the joints.

In addition to permanent volume changes, refractory materials, in common with most others, show expansion as temperature rises, and equivalent contraction as original temperature is restored. This is known in technology as the "reversible thermal expansion," and may be of considerable magnitude. Broadly speaking, the expansion progressively increases with temperature until a temperature at or about that at which the material has been

burnt in making is reached. Here the permanent deformation may set in and obscure the movement. Or the movement may not be obscured until the softening point is reached.

If, in the "under-load" test, the "arm" applying the load is connected to a recording device, a graph of the movement of the test-piece plus that of the thrust-rod may be obtained. With knowledge of the thrust-rod expansion, that of the test-piece may be calculated. But at high temperatures the results also include permanent volume changes and the distortion due to load. The reversible expansion of a brick may be studied by observation of two platinum points mounted on the brick, through two travelling telescopes. Or, again, movement of crystals and brick sections may be observed under the microscope whilst the specimen is heated.

This characteristic is especially to be studied in burnt refractory shapes, and when the total amount of movement is estimated, accommodation in the shape of "expansion joints" in furnace walls can be made. Thus, silica bricks expand up to 2% linear over a temperature range of 1,500° C. Some siliceous bricks show practically negligible reversible expansion (say, 0.2% linear) over a similar range. The reversible expansion of sillimanite bricks can safely be ignored. The reversible expansion is not offset by permanent contraction, since the latter only takes place after the former has become pronounced.

Of far greater importance than the mere estimation of total expansion is the rate at which it takes place. It may be rapid at some temperatures and slow at others, and irregularity of this kind may lead to serious trouble (see Spalling). This serves to illustrate the point that tests on refractory materials must not be considered individually. Thermal expansion is only one of several features affecting the Spalling tendencies of brickwork. (See later.) The irregularity of expansion movement can generally be traced to reversible physical changes in the brick, as will be discussed under silica bricks.

In accommodating the expansion of brickwork in a furnace wall, it is not merely sufficient to provide expansion joints if the walls are not to be damaged. It is necessary to control the rate of heating in order to reduce spalling.

The reversible expansion of materials other than burnt bricks and shapes, as listed above, is not so readily estimated, or its significance appreciated. It is clear, however, that in the case of jointing material, and in the case of patches rammed or "daubed" on to existing brickwork, the thermal expansion of the materials used should be of the same order as that of the brickwork.

MECHANICAL STRENGTH.

This is an essential feature which is receiving close attention in research. Refractory materials have to bear loads and to withstand tensions which are none too easily estimated. These stresses are applied, too, to the cold or relatively cool materials, since in most cases only one face of the mass is exposed to high temperatures. The temperature gradients thus established, considered in conjunction with expansion characteristics, are seen to be responsible for much of the stress.

The relation of cold crushing strength of refractory brick to service value cannot as yet be clearly defined. A high cold crushing strength indicates a well-developed bond or matrix between the coarse grains and gives an indication that particles of the brick will not easily be torn away. The "under load" test previously described can be regarded as a test for the hot crushing strength of the test-pieces. The load can be varied whilst the test-piece is held at a specified temperature, and that load which causes collapse can be recorded. The test gives valuable evidence of the strength at a specified temperature which may be fixed in relation to conditions of use. A study of the type of collapse is useful, too—as it may indicate general softening or merely weakness of the matrix. The viscosity of the matrix assists greatly in increasing rigidity under load.

It would seem that the cold strength of patching and ramming compositions and pastes is a very important feature in affecting their life. Monolithic walls, heated "in position" in the furnace, may develop strength in those parts exposed to the highest temperatures, due to sintering or semi-fusion, but the greater part of the wall is at relatively low temperature, and the material should be capable of developing strength independent of and not destroyed by heat. Another case is that of cupola patching materials, ground ganister, etc., in which, unless properly prepared, there is a tendency to form a glazed skin behind which the material is easily powdered.

Materials such as these should, ideally, possess good mechanical strength at all temperatures, from cold up to maximum furnace temperature.

Tests of the tensile strength of refractories when heated are perhaps more useful still, though they represent a comparatively new departure, and whilst used in research are not a feature of routine testing. The tendency of a refractory brick or test rod to break under tension whilst being heated is important in a consideration of glass tank and pot materials, since it has a bearing on the formation of "stones" in the glass (coarse particles of the tank block of the pot being detached by the viscous "metal" and incorporated in it without being completely dissolved). In metallurgical furnaces such a test may throw light on the problem of slag action, in this case the destruction of the lining being the important feature and the inclusion of particles of refractory in the slag of secondary importance.

RESISTANCE TO ABRASION.

Whilst this depends on the intrinsic properties of the material comprising a brick (magnesite and chrome and carborundum are "harder" than common fireclay), yet it is also dependent on mechanical strength of the "bond" between one grain and another. Its importance is seen in furnaces where the charge whilst solid impinges upon brickwork, and where the flame contains appreciable quantities of mineral ash and dust—e.g., pulverised fuel furnaces.

Mechanical tests are not yet a feature of routine test specifications, but are becoming so well recognised in research work that their ultimate inclusion in such specifications, as and when they are widely adopted, may be taken for granted.

Thermal Expansion of various Refractory Bricks.

After H. F. NORTON in *Journal of American Ceramics Society*, Dec., 1925.
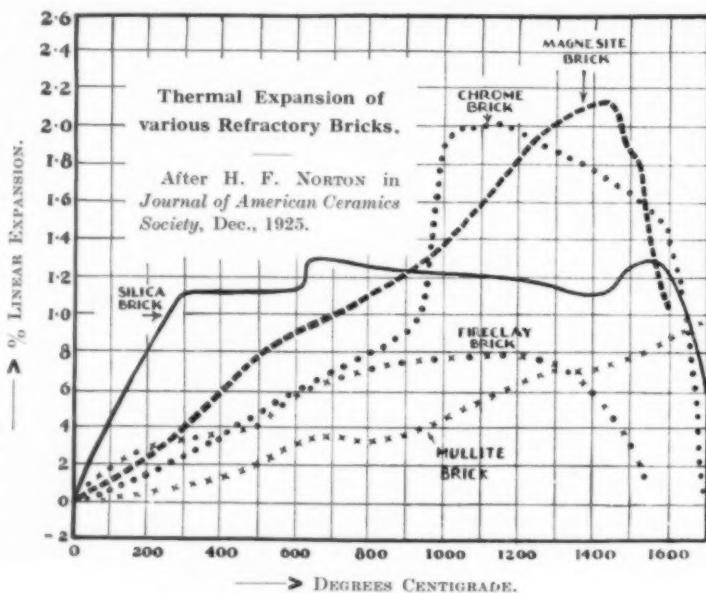
Some Recent Inventions.

AUTOMATIC BILLET DIPPING MACHINERY.

IT is the custom, in connection with the manufacture of tin-plates or sheets, to subject steel billets or bar sections, after they have been heated in the hot mill furnace and cut to the required length, to a dipping operation in a bosh or tank of clean cold water. This operation is usually effected by gripping pairs of the billets or bar sections, the operator performing the desired immersions of the bars or billets and afterwards depositing them in a convenient position for manipulation by the roller man.

A new device, illustrated in Figs. 1 and 2, dispenses with hand labour in the performance of the boshing operation, and effects the separation of the billets from pairs or stacks and passes them singly through the bosh. The appliance consists of an arrangement whereby the separation and immersion processes are mechanically carried into effect, the plates, after immersion being deposited into a convenient position for handling by the roller-man.

A convenient construction and arrangement of parts for carrying the principle into effect is a bed, whereon the heated billets or bar sections, which may be dealt with in pairs or any other number desired, is located at a convenient level, preferably at floor level, and constituted of sheet or bar metal, having a longitudinally extending slot or division. The bosh or tank in which the billets are to be immersed is preferably located below the floor level, and is furnished at one side with an inclined shute, the upper end being located at or about the level of the bed, while its lower end descends into the water in the bosh. Adjoining the upper end of the shute and disposed cross-ways is an adjustable stop-member, which is conveniently carried by a vertical rod or shank. This works in a screw-box or tapped hole in the horizontal or metal section of a " **U** " shape, suitably fixed to the bed. The side edges of the slot in the bed at the part below the stop-member are preferably slightly inclined, and, below that section which extends between the bosh, an endless chain is arranged adapted to be power-driven and furnished with a number of catches which, in the travelling motion of the chain, are successfully carried along the slot in the bed. These act as catches, when in the slot, projecting somewhat upon the bed. The heated billets, cut to the required length and in superimposed pairs, are placed by the operator on the bed of the machine, with one end or edge abutting or practically abutting the stop-member. This stop is adjustable according to the thickness of the billets, so that, while permitting the lower billet to pass, it prevents forward motion of the billet or billets superimposed.

Arranged in the bosh, in a convenient place relative to the lower end of the shute, is an inclined member, which is adapted to receive and support the billet as it descends from the shute, this member being conveniently carried by a bracket fixed to the bottom of the tank. The billets as they are singly received on the inclined supporting member in the bosh are removed out of the bosh by an endless travelling chain, and deposited conveniently for removal

by the roller man. It will be appreciated from the illustrations that this machine allows for the mechanical separation of pairs of bars or stacks of bars or billets, according to what is considered desirable, so that each billet or bar travels singly through the bosh, considerably expediting the boshing operation.

A modification of this principle is illustrated in Fig. 3, in which the bosh is dispensed with. The conveyer and upper length of the conveyers are passed between a battery of spraying jets, which are adapted to eject the spray of cooling liquid under pressure to each side of the bars or billets during their passage between the jets. A further modification is illustrated in Fig. 4. In this instance, a
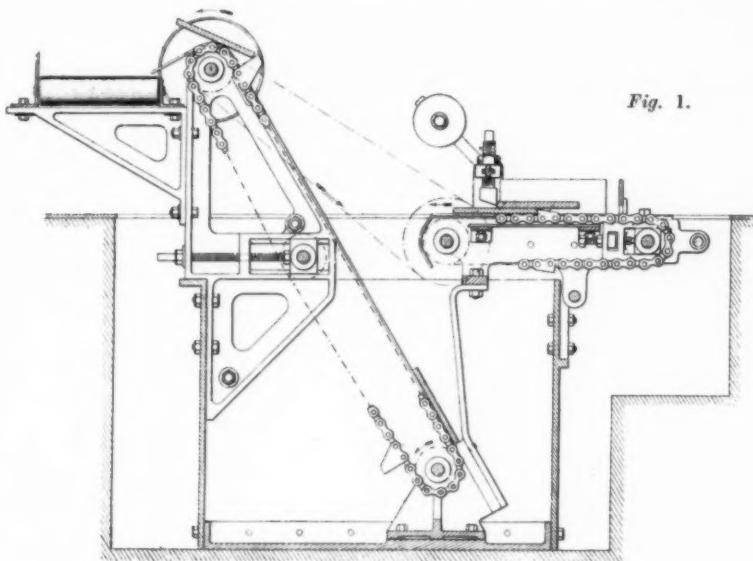
Fig. 1.
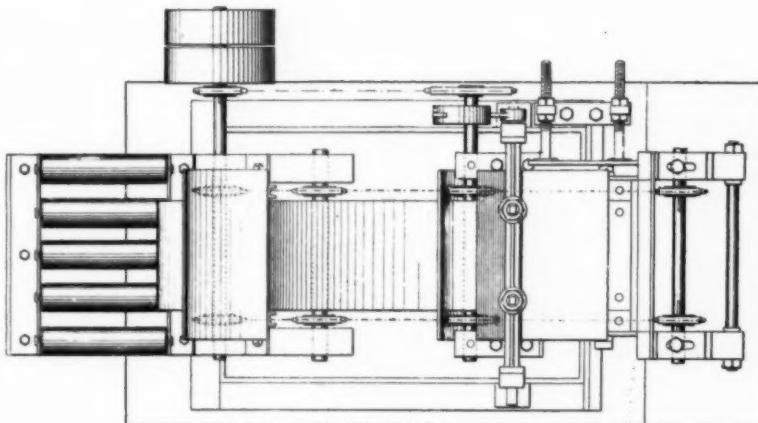
Fig. 2.

bosh is employed which is shallower than the bosh referred to in Fig. 1. The bars or billets as they are separated are deflected by a shute on to the upper section of a pair of endless-chain conveyers, which are passed around sprocket-wheels or wheels arranged at the corners of a rectangular. The upper section of the chain convey being allowed to sag, so that it passes through the cooling liquid contained in the bosh. Near the rear end of the bosh a shute is provided by which the bars or billets are deflected on to a gravity conveyer, which is not shown in the illustration. A further modification of the system is shown in Fig. 5, in which the bosh carries a pair of parallel guides that have a semi-circular shape in cross-section. Between these guides is a paddle-wheel, mounted on a shaft capable of being rotated from a power source. The paddle-wheel is pro-

vided with projections, the forward edges of which are inclined in order to propel the separated pairs as they are directed into the bosh. The rotation of the paddle-wheel carries the pairs through the bosh along the upper surface of the guide-plates.

The device offers many opportunities for modifications according to requirements, and need not be confined to

Fig. 3.

Fig. 4.

Fig. 5.
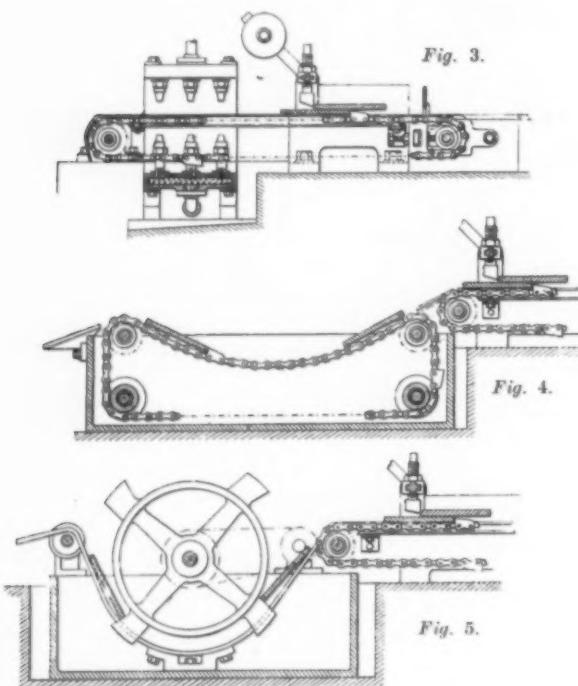
the machines described for passing the bars through the bosh, as other mechanisms can be devised for this purpose within the scope of this device. Furthermore, other forms of conveyers or traverse mechanisms can be substituted for the chain conveyers illustrated ; a reciprocating conveyer can be used, for instance. This appliance is claimed to be useful in the manufacture of tin-plates or sheets, supplying machinery for effecting mechanically the separation of bars or billets, and for passing or traversing the bars or billets through the bosh or equivalent cooling machines.

319,414. H. S. THOMAS and W. R. DAVIES, Patentees. Agents : George Shaw Bowker and Folkes, 35, Temple Row, Birmingham. Complete specifications accepted March 25, 1929.

IMPROVED FORM OF MINE PROP.

CONSIDERABLE progress is being made in the use of steel props in mines as difficulties are gradually being overcome. A device relating to this form of product has recently been patented. It consists of two movable steel members, which are slidably connected with each other, being pressed into frictional engagement when the prop is under load by a clamping device. This clamping device is located on one of the members, and is provided with an eccentric rotary cam, so arranged to contact with the outer surface of the other member that the relative movement occurs under the application of a load. The rotary action of the cam causes the members to be pressed together, and the pressure is increased with the load applied in accordance with the extent to which the prop yields.

Figs. 1 and 2 illustrate a front elevation and a cross-sectional plan respectively of the improved form of mine prop. The members A and B, shown of ⲓ section material, may have any convenient shape. They are held together frictionally by two links, which constitute the clamping

device, which is located on a projection secured to the stationary member.

At one end the links support a cam arranged to contact with moving member A in such a way that, under the application of pressure, the prop yields, and the co-operation of the cam with the movable member serves to press the two members into frictional engagement.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 1.
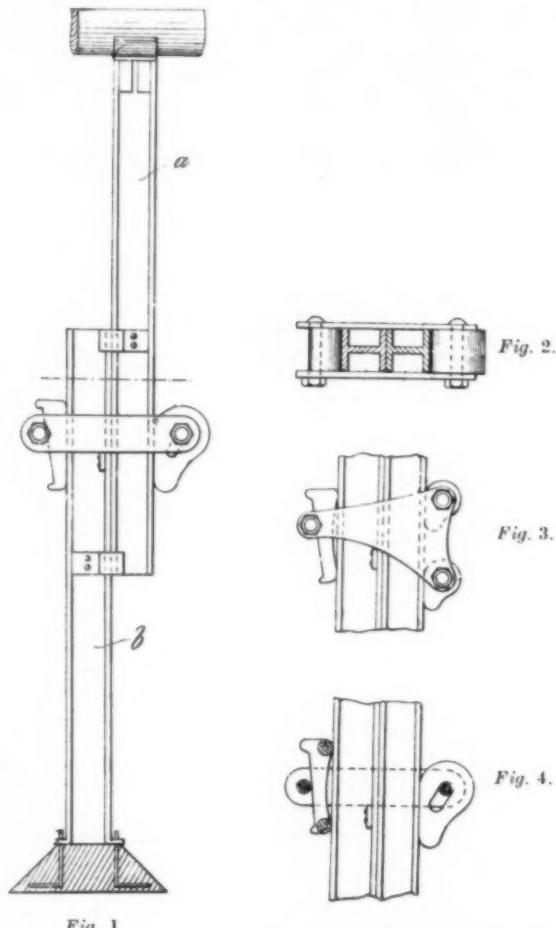
A loose wedge may be used at the other end of the links, set in contact with the fixed member. It will be readily appreciated that the initial pressure with which the cam presses the members into engagement depends upon the extent to which the setting of the loose wedge is forced down, thus enabling the amount of yield of the prop under a particular load to be adjusted, and wear of the clamping parts to be taken up. To permit of further adjustment, the cam may be adjustable by the provision of an inclined slot shown in Figs. 1 and 4.

In order to distribute the pressure which the clamping device exerts upon the members, the links may be modified, as shown in Fig. 3.

A further modification of the loose wedge arrangement can be used with advantage, as is shown in Fig. 4. In this case the wedge or adjusting piece is provided with rollers, which engage the face of the stationary member in order to reduce friction, except between the member A and B. Guide pieces are attached to both members in order that the moving member will slide in relation to the stationary member.

319,800. INTERNATIONAL PROCESSES, LTD., 3, Grosvenor Gardens, S.W. 1, and ARTHUR RYNER. Applicants : Messrs. F. J. Cleveland and Co., 29, Southampton Buildings, Chancery Lane, W.C., agents. Specifications accepted September 30, 1929.

Business Notes and News

Tees-side Possibilities.

Negotiations are reported to be proceeding between Messrs. Dorman, Long and Co., Ltd., and the Furness group of steel and iron companies for the purpose of establishing a working agreement between the two groups which will enable production costs to be reduced and the process of rationalisation of the industry on Tees-side to be carried a stage further. During the last few weeks the works of the two groups have been inspected by the directors and technical advisers of the concerns as a preliminary to the formation of a basis upon which a working agreement could be established.

A Programme involving 4,000 Tons of Steelwork.

The construction programme of the Great Western Railway for this year, in addition to the £5,000,000 to be spent in connection with the Government's schemes to relieve unemployment and the £700,000 the capital equivalent of the remission of Passenger Duty, includes the following items :—161 new passenger vehicles, 30 milk and perishable traffic vehicles, 2,771 freight wagons, 10 King class locomotives, 20 Hall class locomotives, 70 tank engines, 100 horse-drawn vehicles, 56 trailers, 21 modern type weighbridges, and a new steamer for the Fishguard-Rosslare route.

The engineering department propose to relay 380 miles of permanent way and re-sleeper 90 miles of track ; and the reconstruction programme for bridges and other structures composed mainly or wholly of steel will involve the use of about 4,000 tons of steelwork. In addition, £70,000 will be spent on new machinery.

U.S. Steel Combine Completed.

The formation of a new steel combine in the United States of America, as a result of a merger of a number of independent concerns controlled by the Otis banking interests, has been officially confirmed. Known as the Republic Steel Corporation, the new company will be the third largest in America, with total assets of approximately £70,000,000, a combined output capacity of 4,900,000 tons a year, and annual sales of approximately £50,000,000. It will embrace the Republic Iron and Steel Company, Central Alloy Steel Corporation, Donner Steel Inc., and the Bourne Fuller Company. In connection with this new combine a subsidiary company is being formed to carry on the work of metallurgical research, which is to be known as the Republic Research Company.

It is reported that the next merger development is likely to be an amalgamation of the Iceland Steel Company and the Youngstown Sheet and Tube Company, with a view to a possible merger with the Republic group. Such a combine would have an aggregate capacity of nearly 11,000,000 tons a year.

Celebration Banquet.

To commemorate the record sales of October last, General Refractories, Ltd., of Sheffield, gave a banquet to their salesmen and executive staff at the Royal Victoria Hotel, Sheffield, on December 19. Mr. Frank Russell, the chairman and managing director, presided over the gathering.

In the absence of Mr. H. Morgan, Mr. R. W. Matthews, responding to the toast of the new directors, expressed his pleasure in being associated with the company, and his views were supported by Mr. R. B. Kirby.

Mr. Frank Russell, in responding to the toast of success to the firm, paid a very high tribute to all connected with the business, particularly emphasising the loyalty that existed, and which was responsible for the gathering. Continuing his remarks, he said he was proud to celebrate with them a sales figure 100 times the amount of the first month's sale. All sections of the company were equally responsible for the efficient working and the highly satisfactory results obtained, and both the sales and production organisations were referred to in tones of approbation.

An interesting function was performed by Mr. Oliver Whiteley, who presented his co-director, Mr. Frank Russell, with a pen set to commemorate the occasion. A very interesting and pleasant evening, in which speeches were interposed with musical items, terminated with the presentation of prizes to salesmen.

The First Castings at Lochaber.

The first castings in aluminium have just recently been made at the factory of the North British Aluminium Co., near the base of Ben Nevis. The occasion was given prominence by an informal function, at which about a hundred guests were present, and which included a tour of inspection of the works. During the course of the inspection the company gathered round one of the furnaces, which was subsequently tapped and fluid metal allowed to flow into a crucible, from which two ladies were the first to cast it into moulds. The general manager of the company, Mr. W. M. Morrison, stated that though the works appeared large to-day, in the future they would be much larger, and if, as he hoped, they obtained the further Parliamentary powers for which they were asking, Lochaber would probably be amongst the largest producers of aluminium in the world. It is understood that later there will be an official opening of these works.

British Industries Fair.

The Parliamentary Secretary to the Department of Overseas Trade, Mr. G. M. Gillett, M.P., referring to the Committee, which he is appointing to examine the present situation regarding the British Industries Fair, and to consider what means can be adopted to increase still further its utility to British trade, said that in Lord Chelmsford he had secured a chairman who would command the confidence of the business community. Trade fairs, Mr. Gillett continued, had extended throughout the world, and were now accepted as one of the soundest means of doing business. It was pretty certain that few traders would be able to pay more than one visit to his country in the year, and therefore the more the fairs tended to synchronise, the greater would be their attraction and their mutual help to one another. He hoped that, as a result of the inquiry, the British Industries Fair might become truly representative of all branches of British industries.

Trade buyers visiting the Fair in London or Birmingham, from February 17 to 28, will be able to obtain, by special concession of the principal railway companies, return tickets at the rate of single fare and a third. The concession extends to those business men who are making the triangular trip from their own homes, visiting both sections of the Fair. In addition, special rates are available from certain centres and ports on the Continent, and the Swedish Lloyd Steamship Company is among those arranging reduced fares for the occasion.

A Channel Tunnel Difficulty.

The Channel tunnel, from the point of view of boring, said Mr. H. N. Carvalho, private secretary to Baron D'Erlanger, the Chairman of the Channel Tunnel Company, speaking in London recently, was a practical operation, but the real trouble would be to get rid of the excavated earth. Engineers are working on the question, and no doubt the difficulty would be overcome. The tunnel, it is understood, would be concave and in the form of twin tunnels. A drainage tunnel, constructed about 400 ft. below sea level, would be convex in shape, and this latter tunnel would be built first.

Land Reclamation in Greece.

A contract for the Greek Government has been secured by Messrs. Henry Boot and Sons, Ltd., of Sheffield and London, and is estimated at an approximate value of £6,000,000. It is for large reclamation and irrigation works, and is the outcome of considerable negotiation and competition. Over a year ago Mr. Charles Boot, the head of the firm, visited Greece, and in October, 1928, the order was given to the firm. Contracts were signed at that time, and now it is announced that the formal sanction of the Greek Government has been obtained.

The scheme includes the drainage of the plains of Thessaly and Epirus, and this means that huge areas of marsh land will have to be drained. At one part it will be necessary to make a tunnel seven miles long through the mountains to get water away, while many of the engineering problems presented are of the most intricate character. The areas concerned are flat, and will lend themselves to modern schemes of irrigation, which will follow. In the Thessaly Plain there are 535,000 acres which can be freed from the dangers of flooding, and a little over a quarter of this can be irrigated. This land is said to be suitable for growing cotton. The labour needed for the work will be drawn mainly from Greece, but much of the necessary work will be done in England.

IRON AND STEEL REPORT.

THE event of the past month in the British steel trade has been the advance in Association prices for a number of the heavy products. To say that many users were taken by surprise is to put it mildly. Time after time throughout 1929 rumours of impending rises were freely circulated, and time after time buyers took the precaution of covering themselves forward. The only actual increase, however, apart from the one in December, took place in May, and it is not improbable that the end of the year found a number of consumers not too well bought.

The December advance of 7s. 6d. in joists brought these to £8 10s. per ton. The increase in the case of sections, 3 in. and upward bars, and general plates, was one of 5s., bringing selling prices to £8 7s. 6d., £9 7s. 6d., and £9 2s. 6d. respectively. The advance in general plates, however, does not affect all districts, sales in the Lancashire area, for example, being on the old basis of £8 17s. 6d., with frame plates, including surface inspection charges, at £9 2s. 6d. per ton. Boiler plates, also, are unaffected by the decision of the Steel Association, offers being very strong at round £10 for both acid and boiler qualities. Small re-rolled bars range from £8 5s. to £8 7s. 6d. per ton, according to quantity.

As to the outlook at the consuming end of the steel trade, much uncertainty is in evidence, more particularly, perhaps, in the constructional branch, where a number of big schemes are understood to be in abeyance pending possible Budget developments. Many firms of constructional engineers are not too well placed, partly in consequence of this factor, though general economic conditions are, of course, playing an important part. Lancashire boiler makers are contributing little to steel trade activity, the bulk of their work being in the nature of repair jobs. Locomotive builders, however, in various parts of the country have a good deal of work in hand, and in Lancashire, where specifications for boiler plates and other steel material during the closing month of the year had shown a tendency to taper off, there have been signs of revival since the turn of the year, contract deliveries being on an improved scale.

On the shipbuilding side, the immediate outlook either on the North-East coast or on the Clyde is not too bad. At Belfast the prospects are regarded as very bright, nearly 200,000 tons of shipping being either in course of construction or on the order-books.

Ordinary qualities of steel bars, both large and small, meet with only a moderate demand, and re-rollers generally are complaining of a dearth of business. Rollers of small bars for bright-drawing purposes, however, have for some time being doing a satisfactory trade, and some of the leading makers of these are asking as much as six to eight weeks for delivery purposes.

Trade in Continental steel materials on the British markets has been indifferent for some considerable time, and buying interest in this section is of relatively small dimensions. European mills have of late been making strenuous attempts to establish stable minimum prices, but it is questionable whether for long they will be able to stand the test of competition. There is, of course, already a very wide difference between quotations for foreign products, both finished and semi-finished, and the corresponding British prices. In some instances, Continental materials are being offered for delivery to users' works in Lancashire, for instance, at well over £2 a ton below the British parities.

Foundry iron, as it has been during the greater part of the past twelve months, is extremely firm in tendency, and it is by no means certain that prices have reached the peak for the time being. Most users have already bought pretty extensively over the next two or three months, and considering that general foundry trade conditions in most parts leave much room for improvement, contract deliveries of iron have been maintained at a remarkably steady rate.

Some Contracts.

The Electricity Committee of the Metropolitan borough of Hackney has recommended its Council to accept the tender by Simon-Carves, Ltd., boiler engineers, of Manchester, for additions to the boiler plant to be carried out at the Millfields Road generating station. The contract comprises the installation of three huge water-tube boilers, each having an evaporative capacity of 125,000 lb. to 150,000 lb. of steam per hour, travelling grate mechanical stokers, economisers, superheaters, mechanical draught plant, and an independent chimney to each boiler. The contract also includes the whole of the foundations and civil engineering work, a new steel-framed brick boiler-house capable of accommodating six of these enormous boilers, and coal-handling and storage plant of sufficient capacity to deal with the full line of boilers. The total value of the boiler plant contract is in the neighbourhood of £250,000.

In regard to Argentine undertakings, we are informed that an important order has been given for the new Lacroze subway there to three British companies. Fifty-six all-steel cars, their necessary electrical equipment, and electro-pneumatic signalling for the line, to a total value of some £600,000, have been ordered from the Metropolitan-Cammell Carriage, Wagon, and Finance Company, the General Electric Company, of Witton, and the Westinghouse Brake and Saxby Signal Company. We are further informed that these orders were obtained in keen competition with Continental and American manufacturers, price and quality alike favouring the final decision to take British goods.

Capital expenditure on the Rhodesian Railways is expected to amount to £1,750,000 for the current financial year. Some of the more important items of expenditure are : New engines and rolling stock, construction of branch lines, extensive housing programme, and additions to the Victoria Falls Hotel. Additional administrative offices are to be built at Bulawayo to house the increased headquarters staff and to provide accommodation for the stores department at present situated at Umtali. Extensions to the wharf and railway systems at Beira are proposed, involving the construction of new station buildings, the widening of the lighterage wharf, and the provision of two new transit sheds. A new station building is to be erected at Umtali, where the mechanical workshops are to be remodelled, and where a new running shed is to be constructed.

Ruston and Hornsby, Ltd., the Lincoln oil-engine manufacturers, have just received orders for nine marine auxiliary oil engine generating sets, each of 306 k.w. These generating sets will be installed (three sets per vessel) on board three motor cargo liners to be built for the New Zealand Shipping Company.

The Bengal-Nagpur Railway have awarded a contract to the Cleveland Bridge and Engineering Company for seven 300-ft. spans. This steelwork, of a total weight exceeding 4,000 tons, is required in connection with the widening to a double track of the existing single-track bridge over the Rupnurain River between Khaigpur and Calcutta.

During the past few weeks Dennis Bros., Ltd., of Guildford, have delivered 250-gall. pumps to the Wantage and Southampton fire brigades, a 500/700-gall. to the Gramophone Co., Ltd., Hayes, Middlesex, a self-propelled pump to Perth fire brigade, and two " G " type pumps to Chingford and Launceston brigades. They have in hand orders for " G " type fire engines for the Peterborough volunteer fire brigade, and the authorities at Barnes and Pocklington, and for a special police and fire brigade van for Wallasey.

Other orders for bridgework which have been placed this week are : By the Egyptian State Railways, steelwork for bridges, Shelton and Co., Birmingham, £3,000 ; and the South Indian Railway have placed an order for spans for two girder bridges for the Pallachi-Palghat section with Alex Findlay and Co.

The Manchester Corporation Electricity Committee has accepted the tender of Ferranti, Ltd., Hollinwood, for two 10,000 k.v.a. transformers ; and Ferguson, Pailin, Ltd., Manchester, for 33,000 v. three-phase switchgear.

Some Contracts—continued.

Among a number of rolling-mill equipments ordered and installed during the year by Metropolitan-Vickers, Manchester, one of the largest is a 2,300 h.p. equipment for Messrs. Steel, Peech and Tozer, Ltd. This equipment is for a 27-in. reversing intermediate mill. It includes a motor generator set with control in the main fields of the mill motor and generator, and it is provided with a foot-operated master controller to enable the driver to work both the front and back live roller gear, and also the screw gear at the same time. The installation also includes a 200-h.p. motor for driving an edging mill.

This firm has orders for tyre mill equipment in hand for Spain, and also for the Monkbridge Iron Co., Ltd., of Leeds, and Messrs. Taylor Bros., Ltd., of Trafford Park. Several orders are in hand for merchant mill equipments for Spain and Italy.

Orders for blast furnace hoist equipments in hand by Metropolitan-Vickers include one for a 110 h.p. equipment with Ward Leonard control for Messrs. Bolckow Vaughan and Co., Ltd., and one for an equipment, the fifth supplied by this company, for the Stanton Iron Works. Work in hand for the non-ferrous trade includes an equipment for Australia for a lead reversing mill, with Ward Leonard control, and auxiliary motor gear. An interesting installation has been made for British Insulated Cables, Ltd., comprising a 220 h.p. A.C. motor, with contactor controller for driving an 18-in. reversing copper mill. A feature of the equipment is provision for reversal from full speed in one direction to full speed in the other, in the space of 2 secs., repeated continuously at the rate of 16 reversals per minute.

Contracts for railway equipment include an order placed by the L.M.S. Railway for 30 steel passenger brake vans with the Metropolitan-Cammell Carriage, Wagon and Finance Co. Ltd., and an order for the re-signalling of the Metropolitan Railway between Uxbridge and Rayner's Lane, awarded to the Westinghouse Brake and Saxby Signal Co., Ltd.

Overseas contracts include orders placed by the Union of South Africa Railways with the North British Locomotive Co., Ltd., for 18 locomotives of a total cost of £126,000, and by the India Store Department for boiler mountings and fittings for the East Indian Railway awarded to Sir W. G Armstrong and Co., Ltd.

Callenders Cable and Construction Co., Ltd., have been awarded a contract by the India Stores Department, London, for the supply, delivery, and erection of high-tension overhead transmission lines in connection with the Uhl River hydro-electric scheme of the Punjab Government. The value of the contract is £659,585, and will consist of about 400 miles of overhead line together with steel pylons.

The United Steel Companies, Ltd., Sheffield, have obtained South American rail orders which will keep busy their mills at their steelworks at Workington for the first three months of the year. This will be the longest continuous run of activity at the works since 1921.

The North British Locomotive Company, Ltd., Glasgow, has received an order from the South African Railway Administration for eighteen Class 15 C.A. locomotives, at an approximate cost of £126,000.

The Buenos Ayres Great Southern Railway have placed an order with G. R. Turner and Co., Langley Mill, Nottingham, for 100 sheep and cattle wagons. The value of this order amounts to over £50,000.

The Frodingham Iron and Steel Company, Ltd., Scunthorpe, Lincolnshire, have been awarded the contract for the supply of tramway conductor rails for 1930-31, at the price of £7,232, and Dorman, Long and Co., Ltd., Middlesbrough, for the supply of tramway track rails and fishplates for 1930-31 at the price of £53,896, by the London County Council.

Sir John Norton Griffiths and Co., Ltd., have now placed orders as follows in connection with their Assouan Dam contract :—Ten 5-ton steam travelling derrick cranes, six from J. M. Henderson and Co., Aberdeen, and four from F. Butters and Co., Glasgow.

Obituary.

Mr. Alfred Thomas Jenkins, chairman of Messrs. Robert Jenkins and Co., Watling Road, Masborough, died at his home, Farleigh, Herringthorpe, on December 29. Politically, educationally, and industrially, Mr. Jenkins filled many places in Rotherham. He was born in Bristol on July 10, 1852, and took up residence in Rotherham when quite young. Educated locally, he afterwards entered the boiler-making business, founded by his late father. The latter lived long enough to see the wonderful development in the progress of manufacture due to his own energies and those of his son.

Dr. Wilhelm Maybach, the inventor and manufacturer of automobile and aero-engines, died at Stuttgart on December 29, at the age of 84. At the age of 26 Dr. Maybach became the head of the constructional department of the Deutz Gas Engine Factory, then under the management of George Daimler, and he and Daimler played a notable part in the development of the motor-car. Maybach's first achievement was a gas engine with a petrol tank, which was constructed at the Deutz works, where the Otto engine was also first produced. After a visit to the Philadelphia Exhibition, he joined Daimler at Cannstatt, where for ten years they continued to co-operate in the production of high revolution light engines. In 1890, at a small factory of his own, Maybach made what is regarded as his most important contribution to motor-car development, the jet carburetter, based on Butler's experiments. Shortly afterwards he again joined forces with Daimler as technical manager of the newly opened Daimler Motor Company, and there built a series of improvements in motor-car construction, culminating in the Mercédès car. After Daimler's death in 1900, Maybach took over the direction of Daimler works, from which he retired in 1907.

The steel trade of Sheffield has lost one of its best figures by the death of Mr. Robert Senior, C.B.E., J.P., of Forsbacka, Ranmoor. Mr. Senior, who had been ill for several months, was 62 years of age. He was the elder son of the late Alderman George Senior, one of the best known and popular men of his day. Mr. George Senior was a man of marked individuality and genial humour, and his elder son shared these qualities.

Born in 1867, he was educated at Wesley College, Sheffield, and entered his father's business—that of G. Senior and Sons, Ltd., Ponds Forge, Sheaf Street—at an early age, remaining connected with the firm all his life.

After a long illness, Mr. Maxmillian Mannaberg died recently at his residence in Hans-Mansions, at the age of 72. Though he was one of the most important figures in the iron and steel industry, he shunned publicity, and was hardly known to the general public. But the country of his adoption owes him much, for he combined with expert technical knowledge a business capacity and perseverance which enabled him to introduce valuable new processes and to establish large works here, bringing increased trade and employment.

We regret to announce the recent death at the age of 70 of Lieutenant-Colonel Montagu Cradock, associated as a Director of the Metropolitan-Vickers Electrical Company, Ltd., since its early days in 1902. Popularly known as " The Colonel," he endeared himself to everybody connected with the company, staff and workpeople.

Beginning his military career in the Durham Fusilier Militia in 1877, he served through the Afghan campaign, commanded the 2nd New Zealand Contingent, and later the 3rd Mounted Infantry Corps, and the Bushmen's Brigade in the South African War, and in August, 1914, raised the 2nd King Edward's Horse, and commanded that unit until he retired.

One of the oldest of the engineers and shipbuilders on the Clyde, Mr. William Brown, chairman of the old-established firm of William Simons and Co., Ltd., Renfrew, died at his residence, Kilrene, on Christmas Eve. He was 79 years of age, and although in declining health attended his business as recently as Monday of the same week. Apart from his many business associations, Mr. Brown was a member of Renfrew Town Council for 14 years, and as Renfrew's representative was actively identified with the Clyde Navigation Trust. For war services he was honoured with C.B.E., and was a freeman of Renfrew.

MARKET PRICES

ALUMINIUM.

99% Purity			—
Castings, 2.L5 Alloy	lb.		1/3–1/8
„ 2.L8 „	„		1/4–1/9
„ Silicon „	„		—

ANTIMONY.

English	£48	15	0
Chinese	31	0	0
Crude	19	0	0

BRASS.

Solid Drawn Tubes	lb. 12¾d. & 13d.
Brazed Tubes	lb. 14¾d.
Rods Drawn	„ 12¼d.
Wire	„ 10⅜d.
*Extruded Brass	„ 7⅛d.

COPPER.

Standard Cash	£71	10	0
Electrolytic	83	5	0
Best Selected	76	5	0
Tough	76	0	0
Sheets	110	0	0
Wire Bars	84	0	0
Ingot Bars	84	0	0
Solid Drawn Tubes	lb.		15d.
Brazed Tubes	„		15d.

FERRO ALLOYS.

Tungsten Metal Powder	lb.	£0	3	4½
Ferro Tungsten	„	0	3	1½
Ferro Chrome 2 to 4% carbon	„	30	10	0
Ferro Chrome 6% to 8% carbon	„	22	15	0
Ferro Chrome 8% to 10% carbon	„	22	7	6
Ferro Chrome 1% carbon	„	39	0	0
Ferro Chrome Carbon Free	lb.	0	0	11
Metallic Chromium	„	0	2	7
Ferro-Vanadium 25-50%	„	0	12	9
Ferro-Silicon 25%	ton	7	17	6
„ „ 50%	„	11	10	0
„ „ 75%	„	19	0	0
„ Molybdenum 75%	lb.	0	4	2
„ Titanium 23-25%	„	0	0	9
„ Nickel		£170–£175		
„ Cobalt	lb.	0	9	6
„ Manganese loose		12	10	0
„ „ Export		13	10	0
„ Phosphorus 25%		16	0	0

FUELS.

Foundry Coke—			
S. Wales Export	£1	12	6
Sheffield „	1	4	0
Durham „	1	5	0
Furnace Coke—			
Sheffield Export	1	4	0
S. Wales „			
Blast-Furnace Coke, at ovens	0	16	0

GUN METAL.

Commercial Ingots	£71	0	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb. 0	1	2
*Cored Bars	„ 0	1	4

LEAD.

Soft Foreign	£21	6	3
English	22	15	0

MANUFACTURED IRON.

Scotland—			
Crown Bars	£10	5	0
N.E. Coast—			
Rivets	11	10	0
Best Bars	11	5	0
Common Bars	10	15	0
Lancashire—			
Crown Bars	10	15	0
Hoops	13	0	0
Midlands—			
Crown Bars	10	7	6
Marked Bars	12	10	0
Unmarked Bars			
Nut and Bolt Bars	9	2	6
Gas Strip	11	2	6
S. Yorks.—			
Best Bars	11	10	0
Hoops	12	0	0

PHOSPHOR BRONZE.

*Bars, Tank brand, 1 in. dia. and upwards	lb.	1/2
*Cored Bars	„	1/4
†Strip	„	1/4
†Sheet to 10 W.G.	„	1/5
†Wire	„	1/6
†Rods	„	1/5
†Tubes	„	1/9½
*Castings	„	1/4
†10% Phos. Cop. £40 above B.S.		
†15% Phos. Cop. £50 above B.S.		
†Phos. Tin (5%) £30 above English Ingots.		

PIG IRON.

Scotland—			
Hematite M/Nos.	£4	1	0
Foundry No. 1	4	0	6
„ No. 3	3	18	0
N.E. Coast—			
Hematite No. 1	3	19	0
Foundry No. 1	3	15	0
„ No. 3	3	12	6
„ No. 4	3	11	6
Cleveland—			
Foundry No. 3	3	12	6
„ No. 4	3	11	6
Silicon Iron	3	15	0
Forge No. 4	3	11	0
N.W. Coast—			
Hematite	4	1	0
Midlands—			
N. Staffs Forge No. 4	3	14	6
„ Foundry No. 3	3	18	6
Northants—			
Forge No. 4	3	11	0
Foundry No. 3	3	15	0
Derbyshire Forge	3	14	6
„ Foundry No. 3	3	18	6
West Coast Hematite	3	17	6
East „ „	4	0	0
Swedish Charcoal Pig	6	5	0

SCRAP METAL.

Copper Clean	£61	0	0
„ Braziery	57	0	0
„ Wire			—
Brass	43	0	0
Gun Metal	54	0	0

SCRAP METAL—continued.

Zinc	13	10	0
Aluminium Cuttings	65	0	0
Lead	19	0	0
Heavy Steel—			
S. Wales	3	7	6
Scotland	3	9	0
Cleveland	3	3	6
Cast Iron—			
Lancashire	3	5	0
S. Wales	£2	19	6
Cleveland	3	5	0
Steel Turnings—			
Cleveland	2	16	6
Lancashire	2	5	0
Cast Iron Borings—			
Cleveland	2	13	0
Scotland	2	12	0

SPELTER.

G.O.B. Official			—
Hard	£16	10	0
English	20	2	6
India	18	0	0
Re-melted	18	10	0

STEEL.

Ship Plates (Scotland)	£8	15	0
„ „ (N.E Coast)	8	15	0
Boiler „ (Scotland)	10	0	0
„ „ (N.E. Coast)	10	0	0
Sheets 20 W.G.	11	15	0
Angles (N.E. Coast)	8	7	6
„ (Midlands)	8	7	6
Joists	8	10	0
Heavy Rails	8	10	0
Fish-Plates	12	10	0
Light Rails	8	17	6
Sheffield—			
Siemens Acid Billets	9	10	0
Hard Basic	9	12	6
Medium Basic	8	2	6
Soft Basic	7	0	0
Hoops	9	15	0
Manchester—			
Hoops	9	0	0
Bridge and Tank Plates	8	17	6
Angles	8	7	6
Tool Steel, High Speed—			
Finished Bars 18% Tungsten	lb.		2/9
Round and Squares, ½ in. to ½ in.	„		3d.
Under ½ in. to ³⁄₁₆ in.	„		1/–
Round and Squares 3 in.	„		4d.
Flats under 1 in. × ⅜ in.	„		3d.
„ „ ½ in. × ¼ in.	„		3d.

TIN.

Standard Cash	£178	7	6
English	179	5	0
Australian	177	12	0
Eastern	180	7	6
Tin Plates I.C. 20 × 14	box		19/–
Block Tin Cash	£177	15	0

ZINC.

English Sheets	£20	0	0
Rods	34	0	0
Battery Plates	27	0	0

* McKechnie Brothers, Ltd., quoted January 8. † C. Clifford & Son, Ltd.

Pearson & Knowles' Current Basis Prices :—Wrought Iron Bars, £10 15s. 0d. ; Mild Steel Bars, £8 5s. 0d. to £8 10s. 0d. ; Wrought Iron Hoops, £12 ; Best Special Steel Baling Hoops, £9 15s. 0d. ; Soft Steel Hoops (Coopers' and Ordinary Qualities), £9 to £9 5s. 0d. ; C.R. & C.A. Steel Hoops, £12 10s. 0d. to £13 10s. 0d. ; "Iris" Bars, £9 15s. 0d. All Nett Cash.

Trade Circulars and Publications.

We have received a useful type of diary, the pages of which are divided for daily engagement entries over each week. A pleasing feature is the thought for the week, which is appended at the bottom of each page. This form of diary is a useful size for the desk, and is almost indispensable to the busy man. On application will be sent by the United Steel Companies, Sheffield.

It will interest our readers that the Alloy Welding Processes, Ltd., have, in view of the present need for economy in industry, inaugurated a hire service. This will overcome the plant difficulty, as under this system plant can be hired at small monthly rentals, and, in addition, skilled demonstrators will be available to ensure efficiency. Information respecting this system can be obtained on application ; ask for *Bulletin* No. 55.